The Port Authority of New York and New Jersey
Port Department
2021 Multi-Facility Emissions Inventory

Cargo Handling Equipment
Heavy-Duty Diesel Vehicles
Railroad Locomotives
Commercial Marine Vessels

PORT AUTHORITY NY NJ

AIR LAND RAIL SEA

December 2022

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LIST OF ACRONYMS

Act	activity
AIS	automatic identification system
BSFC	brake specific fuel consumption
CF	control factor
CHE	cargo handling equipment
CH_4	methane
CMV	commercial marine vessel
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalents
CSX	CSX Transportation, a US railroad
CVI	Clean Vessel Incentive Program
E	emissions
ECA	North American Emissions Control Area
EF	emission factor
EI	emissions inventory
EPA	United States Environmental Protection Agency
EPAMT	Elizabeth Port Authority Marine Terminal
ESI	Environmental Ship Index
FCF	fuel correction factor
GCT Bayonne	Global Container Terminal at the Port Jersey Port Authority Marine Terminal
GCT New York	Global Container Terminal at Howland Hook Marine Terminal on Staten Island
GHGs	greenhouse gases
g/hp-hr	grams per horsepower hour
g/mi	grams per mile
g/hr	grams per hour
g/MMGTM	grams of emissions per million gross ton-miles
GTM	gross ton-miles
GVWR	gross vehicle weight rating
GWP	global warming potential
HDV	heavy-duty (on-road) vehicle
HFO	heavy fuel oil
hp	horsepower
hp-hr	horsepower hour
IMO	International Maritime Organization
kW	kilowatt
LF	load factor
LPG	liquefied petroleum gas
MDO	marine diesel oil
MOVES3b	EPA's motor vehicle emission estimating model
NO_x	oxides of nitrogen
N_2O	nitrous oxide
NEI	National Emissions Inventory
NJCCC	New Jersey Clean Cities Coalition
NJDEP	New Jersey Department of Environmental Protection
nm	nautical miles
NYCDOT	New York City Department of Transportation
NYNJHS	New York/New Jersey Harbor System

LIST OF ACRONYMS (CONTD)

NYNJLINA	New York/New Jersey Long Island Non-Attainment Area (Ozone)
OGV	ocean-going vessel
PANYNJ	Port Authority of New York and New Jersey
PM_{10}	particulate matter less than 10 microns in diameter
$PM_{2.5}$	particulate matter less than 2.5 microns in diameter
PNCT	Port Newark Container Terminal
ppm	parts per million
R-1	US Surface Transportation Board annual report
RAT	Regional Air Team
RFID	radio frequency identification
SCC	source classification code
SFC	specific fuel consumption
SO_2	sulfur dioxide
TEUs	twenty-foot equivalent units
tonnes	metric tons
tons	short tons
tpy	tons per year
ULSD	ultra-low sulfur diesel
VBP	Vessel Boarding Program
VOCs	volatile organic compounds
VMT	vehicle miles traveled

EXECUTIVE SUMMARY

The purpose of this emissions inventory (EI) report is to present the 2021 mobile source air emissions from activities associated with the marine terminal facilities maintained by the Port Authority of New York and New Jersey (the Authority) and facilities leased to private terminal operators. These mobile emission sources include both land-based mobile sources: cargo handling equipment (CHE), heavy-duty vehicles (HDV), and locomotives; and commercial marine mobile sources (ocean-going vessels (OGV) and harbor craft). This 2021 EI report is an update of the 2020 Multi-Facility Emissions Inventory and one of a series of such reports evaluating and documenting changes in emissions associated with these facilities over time.

ES.1 Trends in Emissions

This report compares the previous year (2020) and baseline year (2006) emissions to 2021 and discusses the findings. The previous year emissions have been adjusted to account for any current year emission estimating methodology changes, if appropriate. This ensures the prior year emissions are comparable to the current year estimates. Table ES.1 summarizes the emissions comparison.

Table ES.1: Emission Comparison, tons per year and %

Inventory Year	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons	Million TEUs
2021	5,296	157	147	296	1,264	79	824,245	8.99
2020	4,942	151	140	278	1,122	67	689,104	7.59
2006	9,498	690	588	497	1,948	4,019	648,284	5.09
2020-2021, Change (%)	**7%**	**4%**	**4%**	**7%**	**13%**	**18%**	**20%**	**18%**
2006-2021, Change (%)	**-44%**	**-77%**	**-75%**	**-40%**	**-35%**	**-98%**	**27%**	**76%**

Table ES.2 compares emissions per million TEU. This comparison illustrates the difference in emissions due to equipment changes and other factors unrelated to the amount of cargo.

Table ES.2: Emission per million TEU Comparison

Inventory Year	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons
2021	589	18	16	33	141	9	91,726
2020	651	20	18	37	148	9	90,841
2006	1,865	135	115	98	382	789	127,289
2020-2021, Change (%)	**-10%**	**-12%**	**-12%**	**-10%**	**-5%**	**0%**	**1%**
2006-2021, Change (%)	**-68%**	**-87%**	**-86%**	**-66%**	**-63%**	**-99%**	**-28%**

Calendar year 2021 was a record year for containerized cargo throughput at the Authority, reaching nearly 9 million TEUs. The increased throughput led to overall higher emissions of all pollutants, but most pollutants decreased relative to the increase in throughput, as shown above in Table ES.2. The following overall conclusions from Table ES.1 and Table ES.2 are summarized below:

- ➢ Cargo throughput increased by 18% in 2021 as compared to the previous year (2020) and it was higher by 76% in 2021 as compared to the baseline year (2006).
- ➢ Oxides of nitrogen (NO_x) related to the Authority marine terminals were 7% higher in 2021 than in 2020, and 44% lower than in 2006. On an emissions-per-TEU basis, emissions in 2021 were 10% lower than the 2020 estimates and 68% lower than the 2006 estimates.
- ➢ Particulate matter less than 10 microns (PM_{10}) related to the Authority marine terminals were 4% higher in 2021 than in 2020 and 77% lower than in 2006. On an emissions-per-TEU basis, emissions in 2021 were 12% lower than the 2020 estimates and 87% lower than the 2006 estimates.
- ➢ Particulate matter less than 2.5 microns ($PM_{2.5}$) related to the Authority marine terminals were 4% higher in 2021 than in 2020 and 75% lower than in 2006. On an emissions-per-TEU basis, emissions in 2021 were 12% lower than the 2020 estimates and 86% lower than the 2006 estimates.
- ➢ Volatile organic compounds (VOCs) related to the Authority marine terminals were 7% higher in 2021 than in 2020 and 40% lower than in 2006. On an emissions-per-TEU basis, emissions in 2021 were 10% lower than the 2020 estimates and 66% lower than the 2006 estimates.
- ➢ Carbon monoxide (CO) related to the Authority marine terminals were 13% higher in 2021 compared to 2020 and 35% lower than in 2006. On an emissions-per-TEU basis, emissions in 2021 were 5% lower than the 2020 estimates and 63% lower than the 2006 estimates.
- ➢ Sulfur dioxide (SO_2) related to the Authority marine terminals were 18% higher in 2021 than in 2020 and 98% lower than in 2006. On an emissions-per-TEU basis, emissions in 2021 were the same as the 2020 estimates and 99% lower than the 2006 estimates.
- ➢ Greenhouse gases[1] (GHG), presented as carbon dioxide equivalent (CO_2e), related to the Authority marine terminals were 20% higher in 2021 as in 2020 and 27% higher as compared to 2006. On an emissions-per-TEU basis, emissions in 2021 were 1% higher than the 2020 estimates and 28% lower than the 2006 estimates.

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[1] Greenhouse gases consisting of the fuel combustion-related gases carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4).

Figure ES.1 graphically illustrates the changes in port-wide emissions of NO_x, PM_{10}, $PM_{2.5}$, SO_2 and CO_2e between the 2006 baseline emissions inventory and the 2021 update, with emission trend lines superimposed over the silver columns illustrating annual TEU throughput (in millions). The figure shows that TEU throughput has increased by 76% since 2006 and emissions of NO_x, PM_{10}, $PM_{2.5}$, SO_2 are lower than in 2006. The CO_2e emissions are 27% higher than in 2006 due to the increased activity and the fact that the emission control technologies and fuel sulfur changes that have reduced the other emissions are not designed to lower carbon emissions.
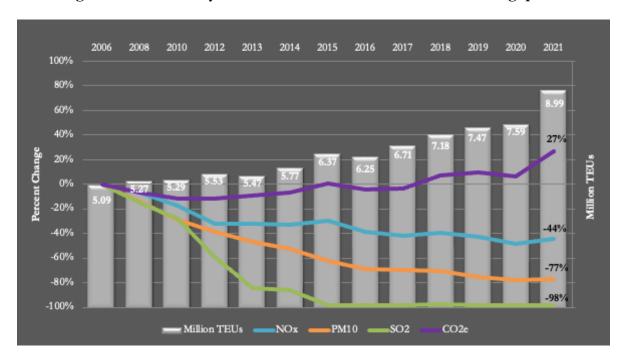
Figure ES.1: Authority Related Emissions Relative to TEU Throughput

Table ES.3 presents the 2021 comparison to baseline year 2006 by source category. Overall, the 2021 emissions are significantly lower than 2006, except for GHG emissions which are higher by 27% due to increased activity associated with the 76% increase in TEU throughput. GHG emissions increases were seen in all source categories, except for ocean-going vessels. Heavy duty trucks and locomotives saw the largest increases.

Table ES.3: 2006-2021 Emission Comparison, tons per year and %

	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons
2021							
Cargo handling equipment	379	28	27	33	175	0.5	166,170
Heavy-duty vehicles	1,747	65	60	100	669	1.4	403,806
Locomotives	327	12	11	25	73	0.3	27,691
Ocean-going vessels	2,537	46	43	131	267	77	191,104
Harbor craft	307	6.2	6.1	6.4	79	0.3	35,475
Total	**5,296**	**157**	**147**	**296**	**1,264**	**79.2**	**824,245**
2006							
Cargo handling equipment	1,503	100	92	132	495	233	154,184
Heavy-duty vehicles	2,911	154	141	139	951	10	224,050
Locomotives	286	10	9	20	44	32	14,710
Ocean-going vessels	4,165	392	314	185	360	3,681	221,638
Harbor craft	633	34	31	21	98	62	33,703
Total	**9,498**	**690**	**588**	**497**	**1,948**	**4,019**	**648,284**
Change between 2006 and 2021 (percent)							
Cargo handling equipment	-75%	-72%	-71%	-75%	-65%	-100%	8%
Heavy-duty vehicles	-40%	-58%	-58%	-28%	-30%	-87%	80%
Locomotives	14%	15%	15%	27%	67%	-99%	88%
Ocean-going vessels	-39%	-88%	-86%	-29%	-26%	-98%	-14%
Harbor craft	-52%	-82%	-81%	-70%	-19%	-99%	5%
Total	**-44%**	**-77%**	**-75%**	**-40%**	**-35%**	**-98%**	**27%**

Key reasons for the emission reductions include regulatory requirements, voluntary actions, and measures from the Clean Air Strategy[2] implemented to date.

> ➢ The North American Emissions Control Area[3] (ECA) continued to be in effect. The ECA requires vessels to burn low sulfur fuel while transiting within 200 nm of the North American coast. The use of fuels with sulfur content of 0.1% or less lowers emissions of SO_2, NO_x and PM emissions from OGVs.
>
> ➢ The PANYNJ Clean Vessel Incentive (CVI) Program[4] continued in 2021. The CVI program provides financial incentive to OGVs that comply with Vessel Speed Reduction (VSR) and those that exceed the current vessel emission standards through the Environmental Ship Index (ESI).
>
> ➢ Use of ultra-low sulfur diesel fuel (ULSD) by all land-based emission sources has reduced SO_2, NO_x and PM emissions.
>
> ➢ The PANYNJ CHE modernization program and fleet turnover continued to introduce new equipment at the terminals, including hybrid and electric-powered equipment when possible.
>
> ➢ The PANYNJ Truck Replacement Program has provided incentives to replace old HDV with newer, cleaner alternatives.
>
> ➢ Truck appointment system at container terminals has reduced truck turn times and queuing.
>
> ➢ Some terminals have modernized their gate operations which reduces truck idling at the in- and out-gates.
>
> ➢ Tier 4i switchers are used for rail-to-barge cross-harbor service.
>
> ➢ Assist tug fleet turnover and repowers accomplished under the New York City Department of Transportation (NYCDOT) and New Jersey Clean Cities Coalition (NJCCC) repower programs have reduced assist tug emissions.
>
> ➢ The new Intermodal Container Terminal Facility provided near-dock rail access for GCT Bayonne, which reduced truck trips and vehicle miles traveled (VMT) to/from Elizabeth's Millennium Marine Rail.

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[2] *https://www.panynj.gov/about/pdf/PANYNJ_CAS_2014_FINAL2.pdf*

[3] *https://www.epa.gov/regulations-emissions-vehicles-and-engines/designation-north-american-emission-control-area-marine*

[4] *https://www.panynj.gov/about/clean-vessel-incentive-program.html*

Table ES.4 presents the 2021 comparison to 2020. In 2021, the 18% increase in TEU throughput resulted in higher overall emissions as compared to 2020 for all pollutants. CHE and OGV emissions increased the most from the previous year. With regard to CHE, the higher emissions are due to more activity, but also in part due to the continued efforts of the Authority and its tenants to improve data collection which, for one terminal, resulted in the collection of more accurate, but higher, operational data. With regard to OGVs, containerships stayed longer at berth and there was slightly more activity overall than during 2020 when cruise ships and tanker vessel calls were lower due to reduced demand during the COVID-19 pandemic.
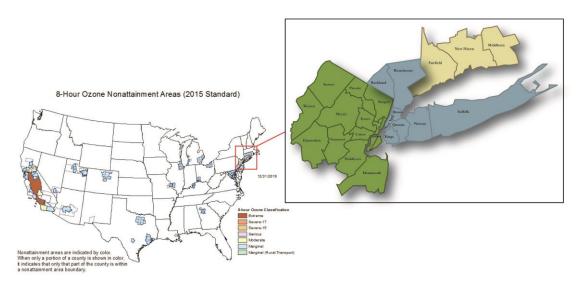
Table ES.4: 2020-2021 Emission Comparison, tons per year and %

	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
	tons	tons	tons	tons	tons	tons	tons
2021							
Cargo handling equipment	379	28	27	33	175	0.5	166,170
Heavy-duty vehicles	1,747	65	60	100	669	1.4	403,806
Locomotives	327	12	11	25	73	0.3	27,691
Ocean-going vessels	2,537	46	43	131	267	77	191,104
Harbor craft	307	6.2	6.1	6.4	79	0.3	35,475
Total	**5,296**	**157**	**147**	**296**	**1,264**	**79.2**	**824,245**
2020							
Cargo handling equipment	297	24	23	27	136	0.4	120,296
Heavy-duty vehicles	1,707	68	63	100	595	1.2	338,844
Locomotives	328	12	11	25	72	0.3	27,087
Ocean-going vessels	2,275	40	37	118	237	65	167,071
Harbor craft	333	7	6	7	82	0.3	35,805
Total	**4,942**	**151**	**140**	**278**	**1,122**	**67**	**689,104**
Change between 2020 and 2021 (percent)							
Cargo handling equipment	27%	17%	17%	22%	29%	36%	38%
Heavy-duty vehicles	2%	-5%	-5%	0%	12%	18%	19%
Locomotives	0%	0%	0%	0%	2%	0%	2%
Ocean-going vessels	11%	15%	15%	12%	13%	18%	14%
Harbor craft	-8%	-6%	-6%	-5%	-3%	-1%	-1%
Total	**7%**	**4%**	**4%**	**7%**	**13%**	**18%**	**20%**

ES.2 Emission Estimates and Comparison to Regional Emissions

The Authority marine terminals included in this report are in an ozone nonattainment area for designated counties in New York, northern New Jersey, and Connecticut.[5]   Figure ES.2 illustrates the counties that are within this nonattainment area.

Figure ES.2: Map of 8-Hour Ozone Nonattainment Areas for New York, Northern New Jersey, Long Island, and Connecticut

The marine terminals are in several of the counties in the states of New Jersey and New York that are within an area that has been called the New York/New Jersey/Long Island Non-Attainment Area (NYNJLINA) in the series of maritime emissions inventories developed by the Authority. The NYNJLINA counties that have been included in the emissions inventories do not include all counties in the current non-attainment area but were recognized by the multi-agency Regional Air Team (RAT), of which the Authority is a member, as an appropriate boundary within which to conduct a series of marine-industry related emissions inventories that initially looked at the commercial marine vessel fleet in the year 2020. Subsequent inventories have been focused on these counties as a means of maintaining consistency with prior reporting and because they remain relevant areas within which to estimate and track emissions related to the Authority marine terminals.

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[5] For example, *https://www.epa.gov/airquality/greenbook/map8hr_2015.html*

The following counties are included in the emissions inventory and in the emissions comparisons:

New Jersey Counties
Bergen
Essex
Hudson
Middlesex
Monmouth
Union

New York Counties
Bronx
Kings
Nassau
New York
Orange[6]
Queens
Richmond
Rockland
Suffolk
Westchester

Figure ES.3 shows the counties in the nonattainment area for the 2008 and 2015 8-hr ozone standard with shading that highlights the counties included in this emissions inventory for emissions comparison to regional emissions. Note that Orange County, New York is included in the emissions inventory and in the regional comparisons although it is no longer within the nonattainment area. It is included because it was historically within the nonattainment area and included in the original NYNJLINA counties.
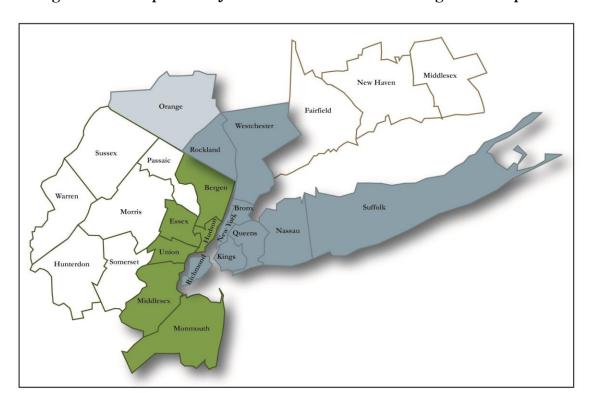
Figure ES.3: Map of NYNJLINA Counties Included in Regional Comparison

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[6] Orange County is included in the emissions inventory and in the regional comparisons although it is no longer within the nonattainment area.
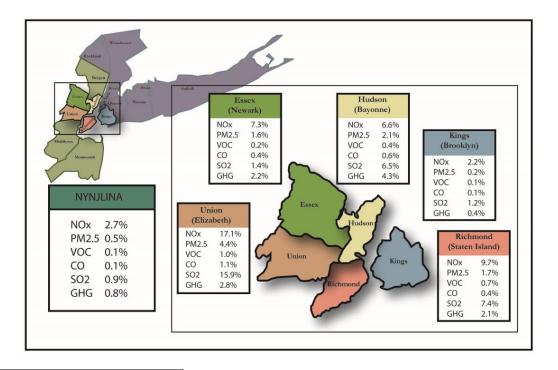
Table ES.5 presents the criteria pollutant and GHG (as CO_2e) emissions by emission source category, the total PANYNJ emissions, the total emissions in the NYNJLINA,[7] and the percentage that the PANYNJ emissions made up of the total NYNJLINA emissions in 2021.

Table ES.5: Emissions Summary by Source Category, tons per year

Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Cargo handling equipment	379	28	27	33	175	0.5	166,170
Heavy-duty vehicles	1,747	65	60	100	669	1.4	403,806
Locomotives	327	12	11	25	73	0.3	27,691
Ocean-going vessels	2,537	46	43	131	267	76.7	191,104
Harbor craft	307	6	6	6	79	0.3	35,475
Total PANYNJ emissions	**5,296**	**157**	**147**	**296**	**1,264**	**79.2**	**824,245**
NYNJLINA emissions	**195,448**	**70,552**	**31,889**	**252,955**	**1,011,780**	**8,568**	**106,102,779**
PANYNJ percentage	**2.7%**	**0.2%**	**0.5%**	**0.1%**	**0.1%**	**0.9%**	**0.8%**

Figure ES.4 illustrates the PANYNJ percentage of emissions in the context of the NYNJLINA emissions (table on the left of the figure) and the percentage that the 2021 PANYNJ emissions make up of all emissions in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure ES.4: Mobile Source Emissions at PANYNJ Marine Terminals Contribution to NYNJLINA and Local Air Emissions

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[7] Emissions are primarily from the 2017 National Emissions Inventory, the most recent year's inventory available from EPA. *https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data*

SECTION 1: INTRODUCTION

Goods from all over the world enter and leave the United States through the largest port complex on the East Coast of North America, the Port of New York and New Jersey (the Port). The Port includes many marine terminals, five of which are under the aegis of the Authority of New York and New Jersey (the Authority).[8]

This inventory does not include emissions from activities linked to the various marine terminals that are entirely privately owned and operated, as they are not under the aegis of the Authority in any way. This inventory also does not include emissions linked to the Authority's non-maritime facilities, such as airports, bridges, and tunnels.

This report furthers ongoing efforts by the Authority's Port Department to assess and evaluate air emissions associated with the Authority's marine terminals, including emissions from cargo handling equipment (CHE), heavy-duty vehicles (HDV), locomotives, and commercial marine vessels (CMV), which include ocean going vessels (OGV) and harbor craft. The Authority's marine terminals are within an area known as the New York/Northern New Jersey/Long Island Ozone Non-Attainment Area (NYNJLINA). The NYNJLINA includes counties in the designated New York/Northern New Jersey/Long Island/Connecticut ozone non-attainment area and includes most of the counties designated by the U.S. Environmental Protection Agency (EPA) in 2005 as a maintenance area for particulate matter 2.5 microns or less in diameter ($PM_{2.5}$).[9]

The purpose of this 2021 emissions inventory is to update the emission estimates with a focus on the Authority's marine terminals. This current study has evaluated the CHE, HDV, railroad locomotive, and CMV emission source categories for the year 2021, which allows for a comparison with the earlier emission estimates for those source categories. The goals of this emissions inventory include:

➢ Estimate the contribution to overall emissions in the NYNJLINA attributable to CHE, HDV, locomotives, and CMV associated with the five Authority marine terminals.
➢ Illustrate trends over time in emissions associated with the five Authority marine terminals.
➢ Reflect, to the extent feasible, the effects of voluntary measures initiated by the Authority and their tenants to reduce emissions.
➢ Continue to help support a case to obtain funding through grants and other programs for enhancing air quality within the NYNJLINA through targeted port-industry related emission reduction initiatives.

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[8] The terminals are listed and discussed below in subsection 1.1.2 Facilities.
[9] In December of 2012, New Jersey submitted a request to the EPA for re-designation to attainment of the annual 24-hour $PM_{2.5}$ standard. On August 13, 2013, the USEPA re-designated New Jersey's 13 nonattainment counties to attainment for the annual and the 24-hr $PM_{2.5}$ NAAQS, effective September 4, 2013, *https://www.nj.gov/dep/baqp/aas.html#annualpm*

1.1 Approach

Methods used to collect data and to estimate and report emissions from the emission source categories are typical of the approach taken by Starcrest, in concert with the EPA and other regulators, for port emissions inventories. The report compares emissions related to terminal operations, including visiting vessels, CHE, HDV, and locomotives with emissions within the NYNJLINA and with regional emissions. It does not include the use of dispersion models to predict ambient concentrations of pollutants or the assessment of health impacts.

The information presented in this report improves the understanding of the nature and magnitude of emission sources associated with the Authority marine terminals and compares the change in emission levels since the previous inventory year and over time since the baseline emissions inventory year of 2006. The activity and operational data collected and used to estimate emissions for each of the source categories is consistent with the latest estimating practices.

1.1.1 Pollutants

This inventory estimates and reports the quantity of emissions from mobile emission sources associated with maritime facilities maintained by the Authority and facilities leased to terminal operators. The estimates are based on activities that occurred during calendar year 2021 and reported in tons per year. Emissions of the following criteria pollutants or precursors include:

- ➢ Oxides of nitrogen (NO_X), an ozone precursor,
- ➢ Particulate matter less than 10 microns in diameter (PM_{10}),
- ➢ Particulate matter less than 2.5 microns in diameter ($PM_{2.5}$),
- ➢ Volatile organic compounds (VOCs), an ozone precursor,
- ➢ Carbon monoxide (CO), and
- ➢ Sulfur dioxide (SO_2).

The following fuel combustion-related greenhouse gas emissions are also included:

- ➢ Carbon dioxide (CO_2)
- ➢ Nitrous oxide (N_2O)
- ➢ Methane (CH_4)

GHG emissions are presented in terms of CO_2 equivalents (CO_2e), a measure that weights each gas by its global warming potential (GWP) value relative to CO_2. The CO_2e emissions include CO_2, methane (CH_4) and nitrous oxide (N_2O). The CO_2e value is calculated by multiplying each GHG's total emissions by its corresponding GWP value from EPA's latest GHG Inventory report[10]. The sum of the three GHGs is reported as one CO_2e value using the following GWP values.

- ➢ $CO_2 - 1$ $N_2O - 298$ $CH_4 - 25$

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[10] *https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks:1990-2019*

1.1.2 Facilities

In 2021, there were no changes to methodology for any of the source categories, however there were some data improvements and assist tug fleet changes that did impact the emissions. For cargo handling equipment, one terminal provided more detailed equipment activity data than in past inventories, which resulted in higher emissions than previous years due to higher equipment operating hours. Prior year's activity for this terminal was based on average port-wide hours of use for that equipment type. For assist tugs, the deployment of newer and more powerful tugboats to assist and escort the larger ships calling the harbor brought newer engines to the fleet. The newer engines resulted in lower emissions overall from harbor craft.

The Authority's New Jersey marine terminals are:

- ➢ Port Newark - container, auto, bulk, and on-terminal warehousing operations
- ➢ The Elizabeth-Port Authority Marine Terminal - container and on-terminal warehousing operations
- ➢ Port Jersey-Port Authority Marine Terminal - container, auto and cruise operations

The Authority's New York marine facilities are:

- ➢ The Howland Hook Marine Terminal - container operations
- ➢ The Brooklyn-Port Authority Marine Terminal - container and cruise operations

Figure 1.1: Location of the Port Authority of New York & New Jersey Marine Terminals

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1.1.3 Major Changes in 2021

In 2021, there were no changes to methodology for any of the source categories. There were some activity changes or data improvements that did impact the emissions. For CHE, a terminal provided better equipment activity data which resulted in higher emissions than previous years due to higher hours of use than what had previously been used as a default based on port wide hours of use average for that equipment type. For assist tugs, a change in fleet mix as newer and more powerful tugboats are being used to assist and escort the larger ships into the harbor and through narrow waterways. The newer engines resulted in lower emissions for harbor craft.

1.2 Report Organization by Section

The sections that follow are summarize emissions results and methodologies for CHE (Section 2), HDV (Section 3), locomotives (Section 4), and CMV (Section 5).

1.3 Summary of Results

Table 1.1 presents the criteria pollutant and CO_2e emissions by source category and compares the PANYNJ totals to the total emissions in the NYNJLINA[11]. EPA's 2020 NEI has not been finalized at the time of this report (Q4 2022). Therefore, the NYNJLINA emissions are from the 2017 NEI, the latest available. The 2017 NEI values were also used for the previous emissions inventory. Comparing 2021 PANYNJ emissions to the latest 2017 NEI is not a complete like-to-like comparison since they are different inventory years which represent different activity levels. However, the comparison serves to generally illustrate the relative contribution of the emission sources covered by this inventory to total emissions in the area.

Table 1.1: Emission Summary by Source Category, tpy

Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Cargo handling equipment	379	28	27	33	175	0.5	166,170
Heavy-duty vehicles	1,747	65	60	100	669	1.4	403,806
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Ocean-going vessels	2,537	46	43	131	267	76.7	191,104
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Total PANYNJ emissions	**5,296**	**157**	**147**	**296**	**1,264**	**79.2**	**824,245**
NYNJLINA emissions	**195,448**	**70,552**	**31,889**	**252,955**	**1,011,780**	**8,568**	**106,102,779**
PANYNJ percentage	**2.7%**	**0.2%**	**0.5%**	**0.1%**	**0.1%**	**0.9%**	**0.8%**

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[11] Criteria pollutant and GHG emissions are from the 2017 National Emissions Inventory:
https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data

Table 1.2 illustrates the percentage contribution of each source category to the total PANYNJ emissions of each pollutant. The OGV and HDV contribute most emissions for the sources included in this inventory.

Table 1.2: Emission Summary by Source Category, %

Source Category	NO$_x$	PM$_{10}$	PM$_{2.5}$	VOC	CO	SO$_2$	CO$_2$e
Cargo handling equipment	7%	18%	18%	11%	14%	1%	20%
Heavy-duty vehicles	33%	41%	41%	34%	53%	2%	49%
Locomotives	6%	7%	7%	9%	6%	0%	3%
Ocean-going vessels	48%	30%	29%	44%	21%	97%	23%
Harbor craft	6%	4%	4%	2%	6%	0%	4%
Total	100%	100%	100%	100%	100%	100%	100%

1.4 Overall Comparison of PANYNJ Emissions

This section compares overall Authority marine terminal-related emissions with county level emission totals as reported in the 2017 NEI. Figure 1.2 illustrates the PANYNJ percentage of emissions in the context of the NYNJLINA emissions (table on the left of the figure) and the percentage that PANYNJ emissions make up of all emissions in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure 1.2: Mobile Source Emissions at PANYNJ Marine Terminals Contribution to NYNJLINA and Local Air Emissions
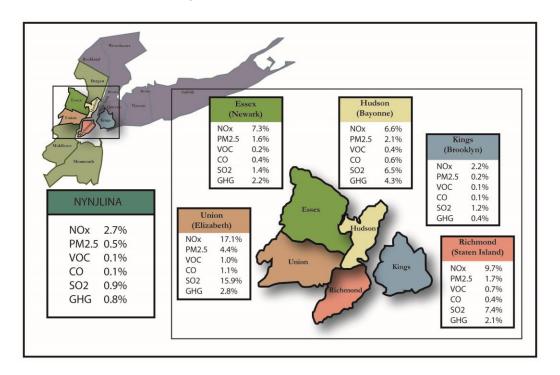
Table 1.3 summarizes by county the estimated emissions from the Authority marine terminal-related activities covered by this report.

Table 1.3: Authority Emissions by County, tpy

County	State	NO$_x$	PM$_{10}$	PM$_{2.5}$	VOC	CO	SO$_2$	CO$_2$e
Bergen	NJ	130	4	4	6	47	0	28,537
Essex	NJ	1,212	36	34	64	286	20	193,165
Hudson	NJ	653	19	18	36	156	9	98,513
Middlesex	NJ	261	9	8	13	96	0	61,140
Monmouth	NJ	266	3	3	11	25	4	11,482
Union	NJ	1,581	61	58	94	452	28	320,654
New Jersey subtotal		**4,103**	**133**	**124**	**224**	**1,061**	**62**	**713,492**
Bronx	NY	13	0	0	1	5	0	3,234
Kings	NY	297	5	5	19	40	5	21,170
Nassau	NY	7	0	0	0	2	0	1,349
New York	NY	5	0	0	0	1	0	710
Orange	NY	72	2	2	4	27	0	17,388
Queens	NY	166	2	2	7	18	3	8,720
Richmond	NY	544	12	11	38	82	9	43,432
Rockland	NY	63	2	2	3	20	0	10,159
Suffolk	NY	12	0	0	0	3	0	1,780
Westchester	NY	13	0	0	1	5	0	2,811
New York subtotal		**1,193**	**24**	**23**	**72**	**203**	**17**	**110,753**
PANYNJ Total		**5,296**	**157**	**147**	**296**	**1,264**	**79**	**824,245**

Table 1.4 lists total emissions of each criteria pollutant by county and state, as reported in the 2017 NEI,[12] which represents the best source of area-wide emissions data and is the most current year available. This comparison shows an overall regional reduction in emissions from all sources, not just those emission sources pertaining to the PANYNJ.

Table 1.4: Summary of NYNJLINA Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Bergen County	NJ	13,039	2,951	1,887	15,100	87,035	172	6,684,339
Essex County	NJ	16,670	4,552	2,067	26,480	70,930	1,454	8,873,281
Hudson County	NJ	9,946	1,494	845	8,264	27,068	143	2,315,613
Middlesex County	NJ	12,498	3,410	1,894	15,466	67,744	231	10,423,700
Monmouth County	NJ	8,988	2,966	1,638	14,384	59,951	154	3,871,333
Union County	NJ	9,235	2,148	1,298	8,957	39,340	174	11,284,879
New Jersey subtotal		**70,375**	**17,520**	**9,629**	**88,651**	**352,068**	**2,329**	**43,453,144**
Bronx County	NY	6,005	2,445	1,118	9,919	29,900	183	2,718,567
Kings County	NY	13,572	4,708	2,560	17,660	59,474	478	5,642,275
Nassau County	NY	15,047	5,959	2,479	19,678	94,281	499	8,346,699
New York County	NY	18,827	11,983	3,903	16,026	82,794	884	6,807,408
Orange County	NY	5,850	3,527	1,414	15,635	33,590	439	2,811,874
Queens County	NY	23,501	6,322	3,035	21,546	85,913	1,736	14,591,117
Richmond County	NY	5,578	1,426	660	5,227	20,511	121	2,112,516
Rockland County	NY	4,553	1,948	852	7,248	24,593	181	2,485,734
Suffolk County	NY	20,379	9,309	3,890	32,692	146,840	1,204	11,626,640
Westchester County	NY	11,763	5,404	2,351	18,672	81,816	515	5,506,804
New York subtotal		**125,073**	**53,032**	**22,260**	**164,303**	**659,712**	**6,240**	**62,649,635**
TOTAL		**195,448**	**70,552**	**31,889**	**252,955**	**1,011,780**	**8,568**	**106,102,779**

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[12] 2017 National Emissions Inventory, the most recent year's inventory available from EPA.
https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data

1.5 Comparison of 2021 Emissions with Earlier Emissions Inventories

One purpose of this emissions inventory is to document changes in emissions over time to reflect the effects of increases and decreases in cargo throughput and changes in the emissions characteristics of the various mobile emission sources associated with the port. While cargo throughput changes are market-driven and are largely beyond the control or influence of the Authority, the Authority influences the emissions from specific emission sources through various programs developed and implemented under the Clean Air Strategy. Authority tenants and other entities involved with international goods movement also take voluntary actions to reduce their emissions.

The previous year (2020) emissions remain the same in this comparison as those published in the 2020 EI report because there were no methodology changes, except for the harbor craft emissions. Harbor craft emissions were re-estimated using the 2021 average emission factors for assist tugs due that reflects the assist tug fleet mix which now includes newer and more powerful tugboats for assist and escort. Therefore, the 2020 harbor craft and port-wide emission estimates published in the prior year 2020 EI report are not the same as the 2020 emissions presented in this report. The 2006 emissions did not need to be re-estimated as this fleet improvement change did not affect the assist tugs used in 2006.

Table 1.5 presents the annual emissions in 2006, 2020, and 2021. The emissions are expressed in both tons per year and as percentage increases or decreases between 2021 and previous years. The last column includes the throughput in million TEUs to compare the increased activity to the emission changes.

Table 1.5: Port Related Emissions Comparison, tpy and %

Inventory Year	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons	Million TEUs
2021	5,296	157	147	296	1,264	79	824,245	8.99
2020	4,942	151	140	278	1,122	67	689,104	7.59
2006	9,498	690	588	497	1,948	4,019	648,284	5.09
2020-2021, Change (%)	**7%**	**4%**	**4%**	**7%**	**13%**	**18%**	**20%**	**18%**
2006-2021, Change (%)	**-44%**	**-77%**	**-75%**	**-40%**	**-35%**	**-98%**	**27%**	**76%**

Table 1.6 presents the 2021 and 2006 emissions comparison by emission source category. Overall, the 2021 emissions are significantly lower than 2006, except for GHG emissions which are higher by 27% due to increased activity associated with the 76% increase in TEU throughput. GHG emissions increases were seen in all emission source categories, except for ocean-going vessels. Heavy duty trucks and locomotives saw the largest increases.

Since 2006, SO_2 emissions saw the greatest reductions due to continued decreasing levels of sulfur in the fuel used by the various emission source categories. Particulate matter (PM_{10} and $PM_{2.5}$) also saw reductions due to a combination of factors including the Authority's truck program that has brought many newer trucks into the fleet of trucks serving the Port's terminals. NO_x emissions are lower due to fleet turnover for all source categories and the CVI program which encourages lower speeds for vessels calling the Port terminals.

Table 1.6: Port Related 2021-2006 Emissions Comparison by Source Category

	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
	tons	tons	tons	tons	tons	tons	tons
2021							
Cargo handling equipment	379	28	27	33	175	0.5	166,170
Heavy-duty vehicles	1,747	65	60	100	669	1.4	403,806
Locomotives	327	12	11	25	73	0.3	27,691
Ocean-going vessels	2,537	46	43	131	267	77	191,104
Harbor craft	307	6.2	6.1	6.4	79	0.3	35,475
Total	**5,296**	**157**	**147**	**296**	**1,264**	**79.2**	**824,245**
2006							
Cargo handling equipment	1,503	100	92	132	495	233	154,184
Heavy-duty vehicles	2,911	154	141	139	951	10	224,050
Locomotives	286	10	9	20	44	32	14,710
Ocean-going vessels	4,165	392	314	185	360	3,681	221,638
Harbor craft	633	34	31	21	98	62	33,703
Total	**9,498**	**690**	**588**	**497**	**1,948**	**4,019**	**648,284**
Change between 2006 and 2021 (percent)							
Cargo handling equipment	-75%	-72%	-71%	-75%	-65%	-100%	8%
Heavy-duty vehicles	-40%	-58%	-58%	-28%	-30%	-87%	80%
Locomotives	14%	15%	15%	27%	67%	-99%	88%
Ocean-going vessels	-39%	-88%	-86%	-29%	-26%	-98%	-14%
Harbor craft	-52%	-82%	-81%	-70%	-19%	-99%	5%
Total	**-44%**	**-77%**	**-75%**	**-40%**	**-35%**	**-98%**	**27%**

Table 1.7 presents the 2021 and 2020 emissions comparison by source category. In 2021, an 18% increase in TEU throughput resulted in higher overall emissions as compared to 2020 for all pollutants. Additionally, post pandemic supply chain disruptions caused significant vessel delays at West Coast ports in 2021 resulting in both vessel and cargo diversions to East Coast ports towards the latter part of the year.

Emissions from CHE and OGV increased the most from the previous year. Regarding CHE, the higher emissions are due to more activity, but also in part due to the continued efforts of the Authority and its tenants to improve data collection which, for one terminal, resulted in the collection of more accurate, but higher, operational data. Regarding ocean-going vessels, containerships stayed longer at berth on average, and there was slightly more vessel activity than during 2020 when cruise ships and tanker vessel calls decreased due to the pandemic.

Table 1.7: Port Related 2021-2020 Emissions Comparison by Source Category

	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons
2021							
Cargo handling equipment	379	28	27	33	175	0.5	166,170
Heavy-duty vehicles	1,747	65	60	100	669	1.4	403,806
Locomotives	327	12	11	25	73	0.3	27,691
Ocean-going vessels	2,537	46	43	131	267	77	191,104
Harbor craft	307	6.2	6.1	6.4	79	0.3	35,475
Total	**5,296**	**157**	**147**	**296**	**1,264**	**79.2**	**824,245**
2020							
Cargo handling equipment	297	24	23	27	136	0.4	120,296
Heavy-duty vehicles	1,707	68	63	100	595	1.2	338,844
Locomotives	328	12	11	25	72	0.3	27,087
Ocean-going vessels	2,275	40	37	118	237	65	167,071
Harbor craft	333	7	6	7	82	0.3	35,805
Total	**4,942**	**151**	**140**	**278**	**1,122**	**67**	**689,104**
Change between 2020 and 2021 (percent)							
Cargo handling equipment	27%	17%	17%	22%	29%	36%	38%
Heavy-duty vehicles	2%	-5%	-5%	0%	12%	18%	19%
Locomotives	0%	0%	0%	0%	2%	0%	2%
Ocean-going vessels	11%	15%	15%	12%	13%	18%	14%
Harbor craft	-8%	-6%	-6%	-5%	-3%	-1%	-1%
Total	**7%**	**4%**	**4%**	**7%**	**13%**	**18%**	**20%**

SECTION 2: CARGO HANDLING EQUIPMENT

This section presents estimated emissions from the off-road equipment used on Authority marine container terminals to handle marine cargo and to support terminal operations, known collectively as cargo handling equipment. The following subsections present estimated CHE emissions in the context of state-wide and NYNJLINA emissions, describe the methodologies used to collect information and estimate emissions, and present a description of the equipment types.

The following privately operated Authority container and cruise terminal tenants have been included in the emission estimates:

 ➢ Red Hook Container Terminal at the Brooklyn-Port Authority Marine Terminal
 ➢ Red Hook Barge Terminal at Port Newark
 ➢ GCT New York at Howland Hook Marine Terminal on Staten Island
 ➢ APM Terminal at the Elizabeth-Port Authority Marine Terminal
 ➢ Maher Terminal at the Elizabeth-Port Authority Marine Terminal
 ➢ Port Newark Container Terminal (PNCT) at Port Newark
 ➢ GCT Bayonne at the Port Jersey-Port Authority Marine Terminal
 ➢ Cape Liberty Cruise Terminals at the Port Jersey-Port Authority Marine Terminal
 ➢ Brooklyn Cruise Terminals at the Brooklyn-Port Authority Marine Terminal

The limited amount of CHE used at bulk terminals is not included in the CHE inventory, but emissions from CMV calling at bulk terminals are included in Section 5.

This section consists of the following subsections:

 ➢ 2.1 - Emission Estimates
 ➢ 2.2 - CHE Emission Comparisons
 ➢ 2.3 - Methodology
 ➢ 2.4 - Description of CHE

2.1 Emission Estimates
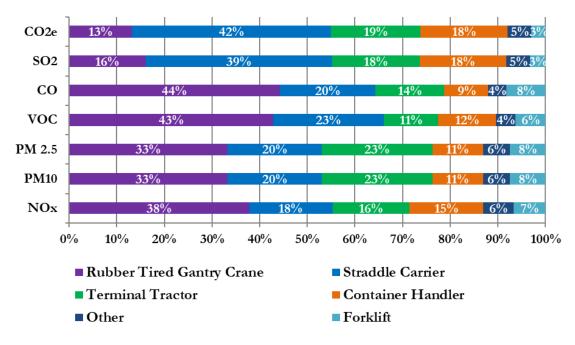
Table 2.1 presents emissions sorted by equipment type for all terminals combined. The equipment types are described later in this section.

Table 2.1: CHE Emissions by Equipment Type, tpy

Equipment Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Terminal Tractor	61	6.4	6.2	3.8	25	0.09	31,170
Straddle Carrier	66	5.5	5.4	7.7	35	0.19	69,433
Forklift	25	2.1	2.0	2.1	14	0.02	4,945
Empty Container Handler	31	1.7	1.6	2.2	8	0.03	10,236
Loaded Container Handler	27	1.3	1.3	1.8	8	0.06	20,147
Rubber Tired Gantry Crane	143	9.2	8.9	14.2	77	0.08	21,940
Reach Stacker	17	0.6	0.6	0.8	4	0.02	6,865
Other Equipment	7	0.9	0.9	0.5	2	0.00	1,433
Totals	**379**	**28**	**27**	**33**	**175**	**0.49**	**166,170**

Figure 2.1 shows the emissions distribution for various pollutants and types of CHE. Straddle carriers and RTG cranes contribute over half of the emissions from CHE equipment, followed by container handlers, terminal tractors, and forklifts.

Figure 2.1: Distribution of CHE Emissions

2.2 Cargo Handling Equipment Emission Comparisons

This subsection presents Authority marine terminal CHE emissions in the context of countywide and non-attainment area-wide emissions. The section also presents a comparison of 2021 CHE emissions with the results of earlier emissions inventories.

2.2.1 Comparisons with County and Regional Emissions
Table 2.2 presents the estimated PANYNJ Marine Terminals CHE emissions in the context of overall emissions in the states of New York and New Jersey, and in the NYNJLINA, including emissions in tons per year and the percentage that PANYNJ CHE emissions make up of overall NYNJLINA emissions.

Table 2.2: Comparison of PANYNJ Marine Terminals CHE Emissions with State and NYNJLINA, tpy

Geographical Extent / Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
NY and NJ	391,399	243,410	88,019	839,013	2,184,903	30,760	200,748,788
NYNJLINA	195,448	70,552	31,889	252,955	1,011,780	8,568	106,102,779
CHE	379	28	27	33	175	0	166,170
% of NYNJLINA Emissions	**0.19%**	**0.04%**	**0.08%**	**0.01%**	**0.02%**	**0.006%**	**0.16%**

Table 2.3 summarizes the PANYNJ Marine Terminals CHE emissions by county and state.

Table 2.3: Summary of CHE Criteria Pollutant Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Bergen	NJ	0	0	0	0	0	0	0
Essex	NJ	39	2	2	3	17	0	22,498
Hudson	NJ	45	3	3	3	21	0	16,596
Middlesex	NJ	0	0	0	0	0	0	0
Monmouth	NJ	0	0	0	0	0	0	0
Union	NJ	257	19	19	24	122	0	111,814
New Jersey subtotal		**340**	**24.9**	**24.1**	**30.7**	**160**	**0.44**	**150,908**
Bronx	NY	0	0	0	0	0	0	0
Kings	NY	10	1	1	1	6	0	5,077
Nassau	NY	0	0	0	0	0	0	0
New York	NY	0	0	0	0	0	0	0
Orange	NY	0	0	0	0	0	0	0
Queens	NY	0	0	0	0	0	0	0
Richmond	NY	29	2	2	2	9	0	10,185
Rockland	NY	0	0	0	0	0	0	0
Suffolk	NY	0	0	0	0	0	0	0
Westchester	NY	0	0	0	0	0	0	0
New York subtotal		**38**	**2.9**	**2.8**	**2.6**	**15**	**0.04**	**15,262**
TOTAL		**379**	**27.8**	**27.0**	**33.3**	**175**	**0.49**	**166,170**

The following figure illustrates the PANYNJ marine terminals percentage of CHE emissions contribution in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure 2.2: PANYNJ Marine Terminals CHE Percent Contribution to Local Air Emissions

2.2.2 Comparisons with Prior Year Emission Estimates
Table 2.4 presents the annual CHE emissions and the percentage difference between 2021, the previous year, and 2006 estimates. In 2021, cargo throughput increased by 18% from the previous year, and emissions increased by 17% to 38%. The higher emissions are due to the increase in operating hours due to the increase in container cargo throughput, but also due to the reporting of more accurate (and higher) equipment operating hours data by one of the Port's terminal operators. This means that a portion of the increases shown in the table do not represent an actual increase in emissions, but rather improved recordkeeping and data collection.

Table 2.4: CHE Emissions Comparison, tpy and %

Inventory Year	NO$_x$ tons	PM$_{10}$ tons	PM$_{2.5}$ tons	VOC tons	CO tons	SO$_2$ tons	CO$_2$e tons	Million TEUs
2021	379	28	27	33	175	0.49	166,170	8.99
2020	297	24	23	27	136	0.36	120,296	7.59
2006	1,503	100	92	132	495	233	154,184	5.09
2020-2021, Change (%)	**27%**	**17%**	**17%**	**22%**	**29%**	**36%**	**38%**	**18%**
2006-2021, Change (%)	**-75%**	**-72%**	**-71%**	**-75%**	**-65%**	**-100%**	**8%**	**76%**

For most pollutants, emissions from CHE were significantly lower in 2021 as compared to 2006 despite the 76% TEU throughput increase. Lower emissions can be attributed to factors such as fleet turnover to cleaner equipment, and increased use of Tier 4 equipment. Emissions of CO$_2$ equivalents were 8% higher in 2021 than in 2006 because the primary contributor to CO$_2$, diesel fuel, is still heavily relied upon to power CHE engines.

The following figure graphically illustrates the changes in CHE emissions between the 2006 baseline emissions inventory and 2021, with emission trend lines superimposed over the annual TEU throughput (in millions).
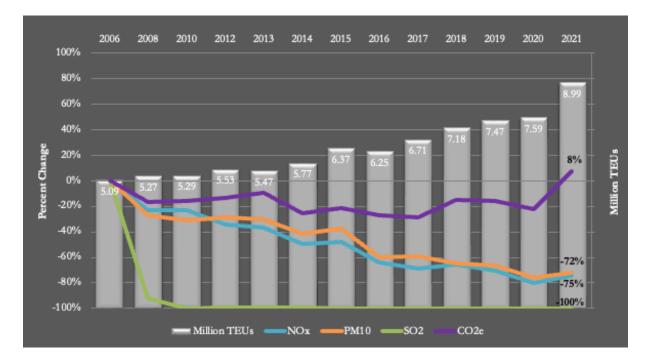
Figure 2.3: CHE Emissions Relative to TEU Throughput

2.3 CHE Emission Calculation Methodology

This subsection describes the methods used to collect information and estimate emissions from CHE.

2.3.1 Data Collection
Data was collected through queries to the terminal operators requesting updates to the information they had provided for the previous emissions inventories. Equipment lists were derived from information maintained by the container and cruise terminal operators. The Port is improving its collaboration with tenants to raise awareness on importance the equipment inventory. This resulted in robust data received for 2021 with one terminal providing more detailed hours of use for equipment than previously received.

2.3.2 Emission Estimating Methodology
The general form of the equation for estimating CHE emissions is:

$$E = EF \times Power \times LF \times Act \times FCF \times CF$$

Where:

E = emissions, grams or tons/year
EF = emission factor, grams of pollutant per unit of work, g/hp-hr or g/kW-hr
Power = rated power of the engine, hp or kW
LF = load factor, which is the ratio of average load used during normal operations as compared to full load at maximum rated horsepower, it is an estimate of the average percentage of an engine's rated power output that is required to perform its operating tasks, dimensionless
Act = equipment's engine activity, hr/year
FCF = fuel correction factor to reflect changes in fuel properties that have occurred over time on emissions, dimensionless
CF = control factor to reflect changes in emissions due to installation of emission reduction technologies not originally reflected in the emission factors.

Emission factors were developed using the equipment specific emission factors output of EPA's MOVES3b emission estimating model.[13] The CHE identified by survey was categorized into the most closely corresponding MOVES3b equipment type. Table 2.5 presents equipment types by Source Classification Code (SCC), load factor, and MOVES3b category name.

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[13] *https://www.epa.gov/otaq/models/moves/*

Table 2.5: MOVES/NONROAD Engine Source Categories

Equipment Type	SCC	Load Factor	NONROAD Category
Portable light set	2270002027	0.43	Signal board / light plant
Wharf crane	2270002045	0.43	Crane
Non-road vehicle	2270002051	0.59	Off-road truck
Front end loader	2270002060	0.59	Front end loader
Aerial platform	2270003010	0.21	Aerial lift
Diesel Forklift	2270003020	0.59	Forklift
Propane Forklift	2267003020	0.59	LPG Forklift
Sweeper	2270003030	0.43	Sweeper / scrubber
Container top loader Empty container handler	2270003040	0.43	Other industrial equipment
Rubber tired gantry crane Straddle carrier	2270003050	0.21	Other material handling equipment
Terminal tractor	2270003070	0.39	Terminal tractor

Table 2.6 lists the population of diesel and propane powered equipment identified at port facilities, listed by common name. The table does not include electric equipment count (105 in 2021).

Table 2.6: MOVES/NONROAD Equipment Category Population List

NONROAD Category	Source Category Code	2006 Count	2020 Count	2021 Count
Aerial lift	2270003010	11	19	21
Crane	2270002045	13	4	4
Diesel forklift	2270003020	0	134	145
Propane forklift	2267003020	87	113	103
Other industrial equipment	2270003040	143	187	199
Other material handling equipment	2270003050	260	438	457
Offroad truck	2270002051	9	16	13
Signal board / light plant	2270002027	12	12	12
Skid-steer Loader	2270002072	0	18	18
Sweeper / scrubber	2270003030	2	3	3
Terminal tractor	2270003070	350	420	418
Totals		**887**	**1,364**	**1,393**

For each calendar year, the MOVES3b model was run to output emission factors in grams/hp-hr for each of the MOVES3b equipment types by fuel type, horsepower group and model year. The model year groups are aligned with EPA's nonroad equipment emissions standards. The PANYNJ estimates of CHE emissions from each piece of equipment is based on the equipment's model year, horsepower rating, annual hours of operation, and equipment-specific load factor assumptions. Summaries of these estimates are presented in the next subsection.

The MOVES3b model contains a load factor and default conditions for each source category. A control factor was applied to equipment identified as being equipped with on-road engines. Ambient temperatures do not significantly affect diesel exhaust emissions; therefore, they were estimated as ranging from approximately 24 to 86 degrees Fahrenheit.

2.4 Description of Cargo Handling Equipment

The equipment inventoried for the container terminals was limited to landside equipment greater than 25 horsepower (hp) and not designed for highway use. While the equipment is generally termed "cargo handling equipment," the equipment used at these terminals can be separated into primary cargo handling equipment, used directly in handling cargo, and ancillary equipment, which has uses other than directly moving cargo (such as sweepers and fuel trucks).

The majority (86%) of equipment is diesel powered, as illustrated in Figure 2.4. The inventory also includes 103 propane powered forklifts and 105 pieces of electric equipment. The electric equipment includes two aerial platforms, 23 forklifts, 24 RMG cranes, and 56 ship to shore cranes. In 2021, there are fewer electric forklifts which resulted in overall less electric equipment in addition to more diesel equipment than the previous year.
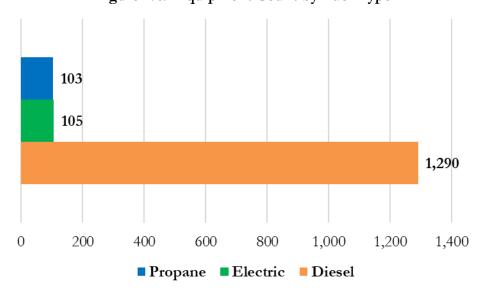
Figure 2.4: Equipment Count by Fuel Type

Table 2.7 summarizes the 2021 fleet characteristics of the CHE, including electric equipment, in terms of equipment count, model year, horsepower, and annual operating hours. As noted above, emissions were estimated using equipment-specific values for each piece of equipment. When the model year, horsepower or hours of use was unknown for a specific piece of equipment, the averages shown below were used as defaults.

Table 2.7: Cargo Handling Equipment Characteristics

Equipment Type	Count	Power (hp)			Model Year			Annual Activity Hours		
		Min	Max	Average	Min	Max	Average	Min	Max	Average
Aerial platform	23	49	83	61	1998	2018	2010	57	118	91
Chassis Flipper	1	155	155	155	2013	2013	2013	0	0	0
Crane	4	900	950	925	1981	1999	1991	23	498	261
Empty Container Handler	76	160	252	204	1996	2021	2013	128	5,853	2,455
Forklift	271	42	350	103	1987	2021	2011	0	3,165	472
Light Tower	12	50	50	50	2001	2001	2001	0	466	177
Reach Stacker	42	200	382	331	2001	2021	2012	45	3,290	1,236
RMG Crane (electric)	24									
RTG Crane	60	450	1,000	567	2001	2014	2005	406	3,383	1,964
Skid Steer Loader	18	38	49	47	2004	2007	2005	66	144	107
Straddle Carrier	397	193	450	354	2006	2021	2016	0	5,866	2,676
STS Crane (electric)	56									
Sweeper	3	38	38	38	2005	2019	2013	0	0	0
Top Handler	80	284	388	357	2004	2020	2014	209	4,872	1,735
Tractor	4	38	38	38	2014	2014	2014	10	14	12
Truck	13	240	325	263	2002	2016	2009	0	1,205	452
Yard tractor	414	145	245	170	1999	2021	2014	0	5,173	1,585
Total	**1,498**									

Figure 2.5 illustrates the total population distribution of the CHE by equipment type and separating the electric equipment into its own equipment category.

Figure 2.5: Population Distribution of CHE

Table 2.8 presents summary data on the diesel engines in the 2021 inventory for the 1,290 diesel engines. In 2021, only 12% of the diesel equipment were equipped with Tier 0 through Tier 2 engines as equipment turnover to Tier 4 engines continued. The table includes diesel equipment count only and does not match the overall equipment count since electric and propane equipment is not included in the diesel tier count table.

Table 2.8: CHE Diesel Equipment Tier Count

Equipment Type	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4i	Tier 4f	Unknown	Total
Empty Container Handler	0	1	4	21	15	35	0	76
Forklift	8	17	10	8	58	42	2	145
Loaded Container Handler	0	0	2	17	8	53	0	80
Reach Stacker	0	2	8	5	12	15	0	42
RTG Crane	0	7	30	18	3	2	0	60
Straddle Carrier	0	0	0	41	47	309	0	397
Terminal Tractor	0	6	20	74	37	277	0	414
Other	4	15	10	6	3	29	9	76
Total	**12**	**48**	**84**	**190**	**183**	**762**	**11**	**1,290**
Percent	**1%**	**4%**	**7%**	**15%**	**14%**	**59%**	**0.9%**	

Table 2.9 shows the 2021 CHE energy consumption for propane and diesel equipment by Tier level. About 90% of total equipment energy usage in terms of kWh is from diesel Tier 3 and Tier 4 equipment. The newer pieces of equipment are being used more, especially Tier 4, and produce lower emissions.

Table 2.9: CHE Energy Consumption

Engine Type and Tier	Energy Consumption kWh	Percent Total
Propane	448,913	0.2%
Other Diesel	313,012	0.2%
Diesel Tier 0	337,242	0.2%
Diesel Tier 1	2,117,974	1%
Diesel Tier 2	16,446,525	9%
Diesel Tier 3	27,092,328	14%
Diesel Tier 4 int	19,189,327	10%
Diesel Tier 4 fin	125,424,243	66%
Total	**191,369,564**	**100%**

The following Figures 2.6 through 2.10 show examples of the most common types of CHE: terminal tractor, straddle carrier, loaded container handler, empty container handler, and forklift.

Figure 2.6: Example Terminal Tractor   **Figure 2.7: Example Straddle Carrier**

Figure 2.8. Example Loaded Container Handler

Figure 2.9. Example Empty Container Handler
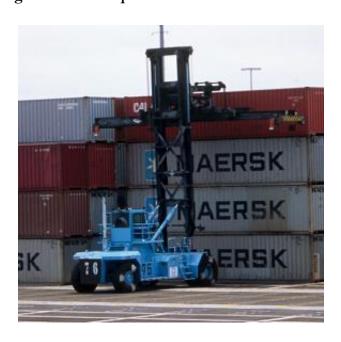
Figure 2.10. Example Forklift

SECTION 3: HEAVY-DUTY VEHICLES

This section presents estimated emissions from HDVs that visit the container terminals, warehouses, and automobile handling facilities within the Authority marine terminals. An example of an HDV included in the inventory is the diesel-powered road truck that calls at a marine terminal to pick up or drop off a container. This type of HDV is by far the most common vehicle operating at the Authority marine terminals. The following subsections present the HDV emission estimates, describe the methodologies used to collect information and estimate emissions, and present a description of the equipment types. This Section 3 consists of the following subsections:

  ➢ 3.1 - HDV Emission Estimates
  ➢ 3.2 - HDV Emission Comparisons
  ➢ 3.3 - HDV Emission Calculation Methodology
  ➢ 3.4 - Description of HDVs

3.1 Heavy-Duty Vehicle Emission Estimates

Emissions have been estimated for HDVs traveling within the marine terminals associated with the Authority and on public roads within the inventory domain. On-terminal activity, which includes the operation of trucks while at warehouses as well as within the boundaries of the container and automobile terminals, has been evaluated to include both driving emissions and idling emissions from trucks waiting to enter the terminal to pick up or drop off cargo. The on-road emission estimates include the idling assumptions built into the emission estimating model used (as described in subsection 3.3.2) so separate idling emissions are not presented for on-road HDV operation.

The HDV emissions were estimated using the MOVES3b emission estimating model. The totals of on-terminal and on-road emissions are presented in Table 3.1.

Table 3.1: Total Marine Terminal Emission Estimates, tpy

Activity Component	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
On-Terminal Driving	100	4.1	3.8	6.5	44	0.07	19,864
On-Terminal Idling	184	10	9	19	73	0.09	25,203
On-Road Driving	1,463	51	47	74	552	1.22	358,740
Totals	**1,747**	**65**	**60**	**100**	**669**	**1.38**	**403,806**

A portion of the emissions presented above originate from trucks owned by Authority tenants. The remaining emissions are from trucks that are owned by companies that are not directly associated with the Authority. Trucks owned by tenants of the Authority made up approximately 3.4% of all trucks that are tagged to enter Authority-leased (tenant) facilities. The remaining trucks that service Authority tenant facilities are owned or managed by

companies that are not associated with the Authority. The emissions attributed to trucks owned or managed by tenant and non-tenant companies is presented in Table 3.2. Emissions have been allocated between tenants and non-tenants using 3.4% tenant truck percentage, assuming all trucks tagged to enter Authority facilities operate an equivalent number of miles in accomplishing their business. Table 3.2 shows that most HDV emissions associated with the Authority arise from trucks owned or managed by companies that are not associated with the Authority.

Table 3.2: HDV Emissions from Tenant and Non-Tenant Trucks, tpy

Truck Owner Status	Percent of Tags	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Tenant trucks	3.4%	60	2.2	2.0	3.4	23	0.05	13,768
Non-tenant trucks	96.6%	1,688	63	58	96	646	1.33	390,038
All Trucks	**100.0%**	**1,747**	**65**	**60**	**100**	**669**	**1.38**	**403,806**

3.1.1 On-Terminal Emissions
Summaries of HDV driving and idling emissions by state and mode are presented in Table 3.3.

Table 3.3: Summary of HDV On-Terminal Emissions by State, tpy

Activity Component	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
New Jersey							
On-Terminal Driving	99	4.1	3.8	6.4	43	0.07	19,644
On-Terminal Idling	170	9	8	18	68	0.08	23,257
New Jersey subtotal	**269**	**13**	**12**	**24**	**111**	**0.15**	**42,901**
New York							
On-Terminal Driving	1.1	0.05	0.04	0.07	0.5	0.001	220
On-Terminal Idling	14	0.8	0.7	1.4	5.5	0.01	1,946
New York subtotal	**15**	**0.8**	**0.7**	**1.5**	**5.9**	**0.01**	**2,166**
Total NJ & NY	**284**	**14**	**13**	**26**	**117**	**0.15**	**45,067**

3.1.2 On-Road Emissions

Table 3.4 presents estimates of on-road emissions in tons per year by state from container terminal trucks.

Table 3.4: Summary of HDV On-Road Emissions by State, tpy

State	VMT	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
New Jersey	166,721,040	1,314	46.0	42.3	66.5	495.7	1.10	322,248
New York	18,879,788	149	5.2	4.8	7.5	56.1	0.12	36,492
Total	**185,600,828**	**1,463**	**51.2**	**47.1**	**74.1**	**551.9**	**1.22**	**358,740**

3.2 HDV Emission Comparisons by County and Region

In this section, Authority marine terminal-related truck emissions are compared with all emissions in the NYNJLINA on a county-by-county basis. Overall county-level emissions were excerpted from the most recent NEI numbers,[14] which are from the 2017 NEI. The extent to which the NEI estimates of on-road emissions were prepared using either the MOVES2014a/b or MOVES2010 models (predecessors to MOVES3), is not known, nor is the magnitude of changes in the county-wide emissions over the years since the NEI was compiled, so the percentage comparisons presented here should be considered as approximate. This section also presents a comparison of 2021 HDV emission estimates with the results of the previous year (2020) and baseline (2006) emissions inventories.

3.2.1 Comparisons with County and Regional Emissions

Table 3.5 presents the estimated HDV criteria pollutant and GHG emissions in the context of overall emissions in the states of New York and New Jersey, and in the NYNJLINA counties. This table includes emissions in tons per year and the percentage that PANYNJ HDV emissions make up of overall NYNJLINA emissions. Table 3.6 summarizes estimated criteria pollutant emissions from the Authority marine terminal HDV related activities reported in this current inventory, at the county level.

Table 3.5: Comparison of PANYNJ Marine Terminals HDV Emissions with State and NYNJLINA Emissions, tpy

Geographical Extent / Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
New York and New Jersey	391,399	243,410	88,019	839,013	2,184,903	30,760	200,748,788
NYNJLINA	195,448	70,552	31,889	252,955	1,011,780	8,568	106,102,779
Heavy-Duty Diesel Vehicles	1,747	65	60	100	669	1	403,806
% of NYNJLINA Emissions	**0.89%**	**0.09%**	**0.19%**	**0.04%**	**0.07%**	**0.02%**	**0.38%**

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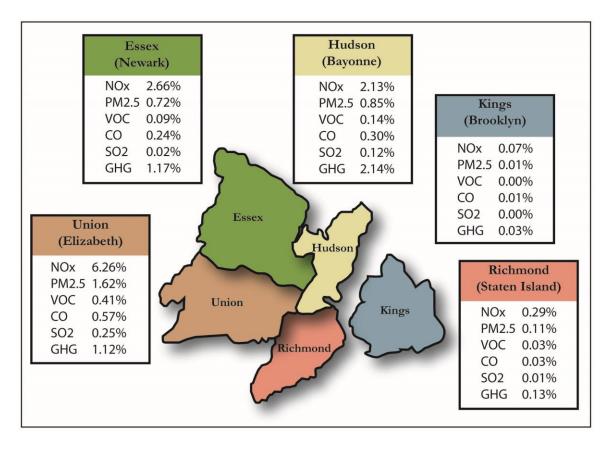
[14] Accessed at: *https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data*

Table 3.6: Summary of Heavy-duty Vehicle Emissions by County (on-terminal and on-road), tpy

County	State	NO$_x$	PM$_{10}$	PM$_{2.5}$	VOC	CO	SO$_2$	CO$_2$e
Bergen	NJ	106	3.7	3.4	5	40	0.09	25,956
Essex	NJ	443	16.2	14.9	25	170	0.35	103,981
Hudson	NJ	212	7.8	7.2	12	81	0.17	49,455
Middlesex	NJ	243	8.5	7.8	12	91	0.20	59,467
Monmouth	NJ	1	0.0	0.0	0	0	0.00	252
Union	NJ	578	22.9	21.1	37	224	0.43	126,038
New Jersey subtotal		**1,583**	**59**	**54**	**91**	**607**	**1.25**	**365,149**
Bronx	NY	13	0.5	0.4	1	5	0.01	3,210
Kings	NY	9	0.4	0.3	1	3	0.01	1,923
Nassau	NY	5	0.2	0.2	0	2	0.00	1,181
New York	NY	2	0.1	0.1	0	1	0.00	493
Orange	NY	70	2.5	2.3	4	27	0.06	17,243
Queens	NY	9	0.3	0.3	0	3	0.01	2,087
Richmond	NY	16	0.8	0.7	1	6	0.01	2,673
Rockland	NY	25	0.9	0.8	1	9	0.02	6,053
Suffolk	NY	5	0.2	0.2	0	2	0.00	1,204
Westchester	NY	11	0.4	0.3	1	4	0.01	2,591
New York subtotal		**164**	**6**	**6**	**9**	**62**	**0.13**	**38,657**
Total NJ & NY		**1,747**	**65**	**60**	**100**	**669**	**1.38**	**403,806**

The following figure illustrates the PANYNJ marine terminals percentage of HDV emissions contribution in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure 3.1: PANYNJ Marine Terminals HDV Percent Contribution to Local Air Emissions

3.2.2 Comparisons with Prior Year Emission Estimates

Table 3.7 presents annual HDV emissions in 2021, the previous year, and 2006. The table also shows the percentage differences for 2020-2021 and 2006-2021.

Table 3.7: HDV Emissions Comparison, tpy and %

Inventory Year	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons	Million TEUs
2021	1,747	65	60	100	669	1.38	403,806	8.99
2020	1,707	68	63	100	595	1.16	338,844	7.59
2006	2,911	154	141	139	951	10.4	224,050	5.09
2020-2021, Change (%)	**2%**	**-5%**	**-5%**	**0%**	**12%**	**18%**	**19%**	**18%**
2006-2021, Change (%)	**-40%**	**-58%**	**-58%**	**-28%**	**-30%**	**-87%**	**80%**	**76%**

The following figure graphically illustrates the changes in HDV emissions between the 2006 baseline emissions inventory and the 2021 update, with emission trend lines superimposed over columns representing the annual TEU throughput (in millions). The PM_{10} and $PM_{2.5}$ emissions track closely together, with a 58% emission reduction in 2021 as compared to 2006. The CO_2e emissions are 80% higher than in 2006.

Figure 3.2: HDV Emissions Relative to TEU Throughput

The effects of the progressively newer fleet, documented since 2008 and discussed later in this section, show up in the decreases of PM and NO_x emissions since 2006. Continued renewal of the drayage truck fleet, in part resulting from the Authority's Truck Replacement Program, is expected to lead to continued decreases in PM and NO_x emissions as newer, lower-emitting trucks replace older, higher-emitting trucks. For example, trucks newer than model year 2007 emit substantially less PM than older model year trucks, and trucks newer than model year 2010 emit substantially less NO_x than trucks older than 2010. The enhanced model year data collection discussed below provides up-to-date model year distributions that document the changes in the distribution of model years.

3.3 Vehicle Emission Calculation Methodology

This section contains a description of the methodology used to collect data and the process by which emission estimates were developed for HDVs. Figure 3.3 illustrates this process in a flow diagram for on-terminal and on-road activity.
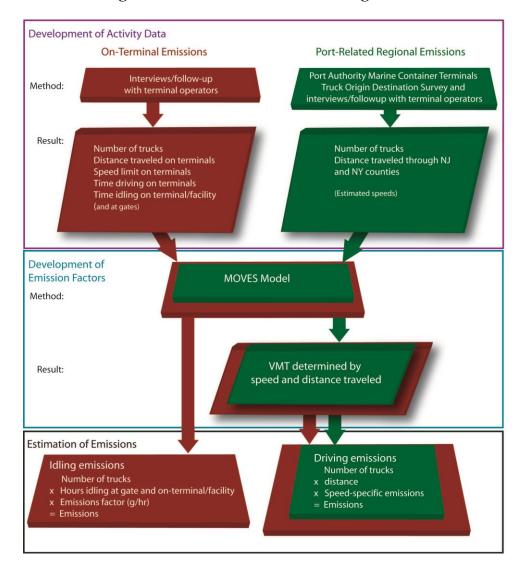
Figure 3.3: HDV Emission Estimating Process

3.3.1 Data Acquisition

Activity data for the HDV emission estimates came from the PortTruckPass (PTP) system, from cargo throughput records, and from contacting facility operators to request an update of the information provided for previous inventories. Because the information requested of facility operators, such as the number of truck visits during the year, the average time that trucks spend on their terminals and the average speed at which they travel, is provided on a voluntary basis, the operators have been reluctant to provide detailed information, based on uncertainty regarding how the Port will use their information. For this reason, many of the on-terminal operating parameters are unchanged from previous inventories. However, the activity data reflect reasonable operating characteristics and the number of truck visits for which emissions are calculated is based on actual changes in cargo throughput from year to year (with more cargo resulting in more truck calls). The characteristics of on-terminal HDV activities used to estimate emissions at the Authority container terminals leased to private operators, are listed in Table 3.8.

Table 3.8: Reported Container Terminal Operating Characteristics

Terminal	Number Truck Calls (annual)	Total Distance (miles)	Total Idle Time (hours)
Container A	2,276,549	3,414,824	1,058,595
Container B	1,335,321	1,335,321	714,397
Container C	1,006,063	1,609,700	392,364
Container D	827,897	827,897	273,206
Container E	403,158	40,316	183,437
Container F	82,456	41,228	36,280

The average idling times were based on information previously provided by the terminals. In addition, the prevalence of idling by trucks waiting at warehouses was evaluated by site observations made on two different days during a previous drayage truck survey conducted in 2008, to account for the fact that not all trucks idle while they are being unloaded or loaded at the warehouses. On average, 35% of trucks were observed to be idling while at the warehouses. While a 3-minute idling limit rule is in place on and around the terminals, the aggregate of several 3-minute (or less) periods of idling during a truck's transit through a terminal (stop-and-go activity) can produce total idling times as shown in the table.

On-Road

Vehicle miles of travel (VMT) were estimated for regional HDV activity by estimating the average distances between the terminals and origin or destination locations in the NYNJLINA or, for trips that start in or extend into adjacent counties or states, to/from the boundary of the NYNJLINA. These VMT estimates were used with the number of truck trips and appropriate emission factors to estimate on-road HDV emissions traveling to and from the container terminals. On-road transport associated with warehouses and auto marine terminals, which follow processing of the marine cargo with freight from other sources, are secondary in nature and are considered part of the regional traffic structure and are therefore not included in this inventory. Truck travel patterns, in terms of where trucks arrive from and depart to, were obtained from a survey of drayage truck origins and destinations (O&D survey) conducted by the engineering firm Hatch[15] in 2017. Starting with the 2017 emissions inventory, these survey results replaced the previous O&D information used for the past several emissions inventories.

Model Year Distribution

Model year is an important characteristic of HDV because emission standards are applicable on a model year basis. Since newer trucks are subject to stricter (lower) emission standards for certain pollutants than older trucks, newer trucks generally emit less than older trucks. A model year distribution characterizes the percentage that each model year makes up of the total number of terminal visits during the inventory year. The distribution is used to develop emission factors that appropriately reflect the specific mixture of model years in the trucks that called at the terminals.

The container terminals at the Authority marine terminals have implemented gate systems that make use of radio frequency identification (RFID) technology to identify and record HDV that are registered as eligible to access the terminals. This is a valuable source of information about the distribution of truck model years in Port goods movement service that has been used to replace the periodic surveys that were conducted in 2008, 2010, and 2012. The PTP combines data from the RFID system and the drayage truck registry, providing a detailed picture of truck calls and model years in a calendar year, providing for a robust model year distribution for a given year. While the data are specifically related to container terminals, the distribution has been used for all truck types covered by the inventory, including automobile transports and trucks calling at the warehouses. While these non-container trucks may differ in age characteristics from the container trucks, they make up a small fraction (approximately 3%) of all truck trips so any inaccuracy introduced by using the container truck distribution to represent all trucks is likely to be insignificant.

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[15] 2017 Origin & Destination Study. Hatch, draft report 2017.

Figure 3.4 below illustrates the changes in model year distributions of the trucks serving the Authority terminals in calendar years 2008, 2010, and 2012 through 2020. For clarity, the model year percentages have been classified into years that were subject to similar emission standards and that therefore have similar emission characteristics. For example, the 2007-2009 group is subject to stricter particulate standards, while the 2010 and later group is subject to tighter NO_x requirements in addition to maintaining the particulate standards.

Figure 3.4 shows the increase of newer model year trucks and the reduction of older trucks from among the vehicles calling at the terminals. In 2021, 58% of the trucks that called the Port have the cleanest engines available, model year 2010 and newer. This turnover has been responsible for much of the emissions benefit seen in the HDV emission source category.
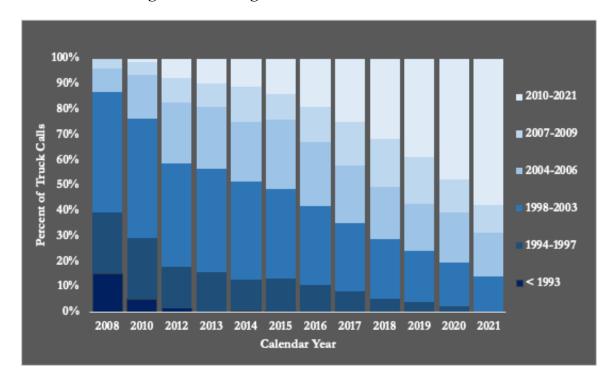
Figure 3.4: Changes in Distribution of Model Years

Figure 3.5 illustrates the model year distribution of HDV during 2021 in more detail. This figure shows that 1998 through 2003 trucks made up 14% of calls, model years 2004 through 2006 made up 17% of calls, model years 2007 through 2009 made up 11% of the calls, and, as noted above, 58% of calls were made by trucks of model year 2010 and newer (up to 2021 model year trucks).

Providing yet more detail, Figure 3.6 breaks out the distribution of the newest model year group, those that are in the lowest emissions group subject to the 2010+ emission standards. This figure shows that the predominant model years were 2011 through 2015, with newer model year trucks (2016 – 2021) making up almost 13% of all calls and 22% of this cleanest group.
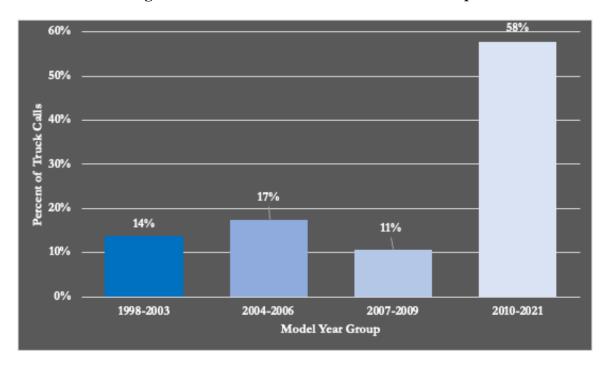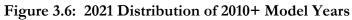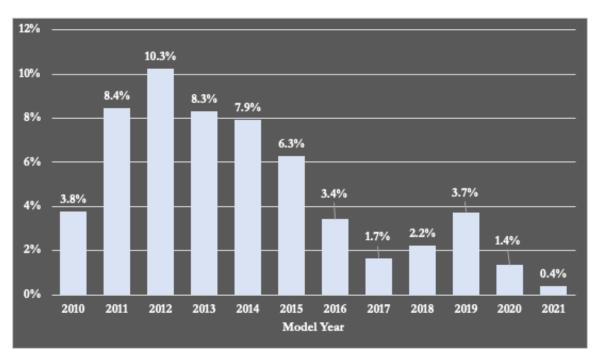
Figure 3.5: 2021 Distribution of Model Year Groups

Figure 3.6: 2021 Distribution of 2010+ Model Years

3.3.2 Emission Estimating Methodology

While specifics vary, the general form of the equation for estimating vehicle emissions is:

$$E = EF \times Act$$

Where:

            E = Emissions
            EF = Emission Factor
            Act = Activity

Two types of activity are considered in estimating drayage truck emissions: engine running with vehicle moving at a given speed or speed profile, and engine idling with vehicle at rest. Running emission factors are expressed in terms of grams per mile (g/mi) while idling emission factors are expressed in terms of grams per hour (g/hr). Therefore, the activity measure used for estimating running emissions is miles and the activity measure used for estimating idling emissions is hours. The emission factor (g/mi or g/hr) is multiplied by the activity measure vehicle miles traveled (VMT) or hours to estimate grams of emissions, which are then converted to pounds or tons as appropriate. The time period covered by the emission estimate corresponds to the time period of the activity measure. For example, an annual VMT figure multiplied by a gram per mile emission factor results in a gram per year emission estimate.

The emission factors have been developed using MOVES3b, which is the latest mobile source emissions model developed by EPA. Vehicle types, time periods, geographical areas, pollutants, vehicle operating characteristics, and road types are supplied by the user. MOVES3b has been used to estimate emission factors for the pollutants included in this emissions inventory, in grams per mile and grams per hour, for combination short-haul trucks of each model year. Combination short-haul truck is the vehicle type in MOVES3b most closely associated with the trucks serving the marine terminals, defined in the model as combination tractor/trailer trucks with more than four tires with a range of operation up to 200 miles. The emission factors developed by model year were used to develop composite emission factors that reflect the actual vehicle age distribution for trucks used at the Authority marine terminals.

The road types in MOVES3b most closely associated with port HDV are "urban unrestricted access," representing the activity of the trucks on marine terminal shared roadways and open public roads in the inventory area, and "urban restricted access," representing the activity of the trucks on the controlled access highways in the area. The emission factors developed for these two road types were averaged to obtain the emission factors used to estimate on-road emissions. The MOVES3b model was also used to develop emission factors for the very slow-speed driving within the tenant terminal boundaries, which averages a reported 15 miles per hour, and for on-terminal idling, both the low-idle experienced during the short-term idling of trucks in normal operation on the container terminals, and high idle rates utilized by automobile transport trucks to load vehicles at the auto terminals. MOVES3b emission factors for exhaust emissions from trucks moving on the road include the incidental idling emissions associated with the drive cycle travel, so these are not estimated separately. The parameters used in a MOVES3b model run are specified in a dataset known as a "runspec"

that is produced during the setup of the model run. Runspecs for the model runs used in this emissions inventory are included in Appendix A.

On-terminal and on-road emissions were calculated in a similar manner, by multiplying the activity value by the relevant emission factor. As an example, a mileage total of 100,000 VMT would be multiplied by the relevant NO_x emission factor (e.g., 11.283 g/mi for on-road travel):

$$\frac{100,000 \; miles/yr \times 11.283}{453.59 g/lb \times 2,000 \; lb/ton}$$

Similarly, for on-terminal idling emissions, total idling hours per year would be multiplied by the NO_x emission factor for idling. As an example:

$$\frac{100,000 \; hours/yr \times 67.732 \; g/mi = 9.0 \; tons/yr}{453.59 g/lb \times 2,000 \; lb/ton}$$

The MOVES3b-derived driving and idling emission factors for the 2021 EI model year distribution of combination short-haul trucks used in the emission estimates are presented in Table 3.9. The on-terminal (g/mi) EF are based on 15 mph average speed, while the on-road (g/mi) EF are based on MOVES3 highway/local average speeds.

Table 3.9: HDV Emission Factors (g/hr and g/mi)

Component of Operation	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2	N_2O	CH_4
Short-Term Idle (g/hr)	57.854	3.138	2.887	5.950	22.530	0.027	8,001	0.083	0.360
Extended Idle (g/hr)	79.940	2.630	2.420	11.616	45.064	0.027	7,776	0.000	1.000
On-Terminal (g/mi)	12.306	0.507	0.467	0.799	5.390	0.008	2,439	0.006	0.061
On-Road (g/mi)	7.151	0.250	0.230	0.362	2.697	0.006	1,752	0.002	0.024

The extended idling emission rates shown in Table 3.8 are applicable for periods of idling above normal engine idling speeds to run equipment needed for safety, comfort, or operation of ancillary equipment. Container and warehouse trucks are not believed to idle for extended periods due to regulations, increased anti-idling signage, and reported verbal warnings from terminal operators. This is supported by observations made by surveyors (including a primary author of this emissions inventory report) during the 2012 drayage truck survey at New Jersey and New York container terminals, when it was observed that HDV were often shut off while not in actual use within or adjacent to the terminals. Automobile transport trucks reportedly operate at increased idle while loading vehicles to run equipment needed for the operation.

Emissions were calculated as tons per year for each maritime operation, with idling and transit activities estimated separately. On-road emissions have been calculated in the same manner as on-terminal emissions, the VMT multiplied by the appropriate emission factor, as listed above. Vehicle miles traveled within each county of the NYNJLINA have been estimated using the Hatch origin-destination study for HDVs servicing the container terminals.

3.4 Description of Heavy-Duty Vehicles

This section contains a description of HDVs including their modes of operation in Port service, and the general types of vehicles. This emissions inventory includes emission estimates from HDV operations at the following facilities:

Table 3.10: Maritime Facilities by Type of HDV Operation

Type of Operation	Marine Facility
Container Terminals	➢ Port Newark Container Terminal (PNCT) at Port Newark ➢ Maher Terminal at the Elizabeth-PA Marine Terminal (EPAMT) ➢ APM Terminal at EPAMT ➢ Global Container Terminal New York at Howland Hook Marine Terminal ➢ Red Hook Container Terminal, LLC secondary barge depot at Port Newark ➢ Global Terminal Bayonne at the Port Jersey-Port Authority Marine Terminal
Auto Marine Terminals	➢ Toyota Logistics at Port Newark ➢ Foreign Auto Preparation Services (FAPS) at Port Newark ➢ BMW at the Port Jersey Port Authority Auto Marine Terminal
On-Terminal Warehouses at Port Newark/EPAMT/BPAMT	➢ Best Transportation, Inc. ➢ East Coast Warehouse ➢ Eastern Warehouse ➢ International Motor Freight ➢ Harbor Freight ➢ MTC Transportation ➢ Mecca & Sons Trucking ➢ Accem Warehouse ➢ Courier Systems ➢ DiPinto ➢ TEV Trucking ➢ TRT International

3.4.1 Operational Modes

HDVs are used extensively to move goods, particularly containerized cargo, to and from the marine terminals that serve as a bridge between land and sea transportation. HDVs deliver goods to local, regional, and national destinations. Over the course of the day, HDVs are driven onto and through a container, warehouse and/or auto-handling facilities where they deliver and/or pick up goods. They are also driven on the marine terminal roadways, which are roads situated within the boundaries of major, multi-facility terminals such as Port Newark/ Elizabeth Port Authority Marine Terminal (EPAMT), and on the public roads outside these complexes.

Areas of activity for which emissions have been estimated include on-terminal (dropping off or picking up cargo) and on the public roads throughout the counties discussed in Section 1.

> ➤ On-terminal operations include driving through the terminal to drop off and/or pick up cargo, and idling while queuing, loading/unloading, and departing the terminal.
> ➤ On-road operations consist of HDV origin/destination moves from/to the first point of rest within, or out to the limits of, the NYNJLINA region.

The "first point of rest" is the location at which import cargo (received from ships) is transferred from the first means of transport out of the arrival terminal to the ground or to another mode of transportation (such as truck-to-rail transfer). This occurs, for example, at the warehouse facilities when a container is moved from ship-side to a warehouse for transloading, which is the process of unloading import shipping containers and repacking them into other containers or enclosed trailers for transport to multiple destinations. Some warehouses are located in the vicinity of the Authority marine terminals while others are located within 100 miles of the Port. For example, HDVs transport cargo from the port area to warehouses located in the lower Hudson Valley, New York, northeastern Pennsylvania, the Philadelphia area, and northern Baltimore /Delaware area.

3.4.2 Vehicle Types

This inventory deals exclusively with diesel fueled HDVs because these are by far the most prevalent type of vehicle in this service. The most common configuration of HDV is the articulated tractor-trailer (truck and semi-trailer) having five axles, including the trailer axles. The most common type of trailer in this study area is the container trailer (known as a chassis), built to accommodate standard sized intermodal cargo containers. Another common configuration is the bobtail, which is a tractor traveling without an attached trailer. Other types include auto-carriers and flatbeds. These vehicles are all classified as HDVs regardless of their actual weight because their classification is based on GVWR. The emission estimates developed by the current regulatory model (discussed in subsection 3.3) do not distinguish among different configurations (e.g., whether loaded or unloaded). In the 2008, 2010, and 2012 HDV model year surveys, most of the HDVs were in the heaviest category, 60,000 to 80,000 pounds GVWR, with the remainder being in the 33,000 – 60,000-pound category.

Figure 3.7 is an illustration of a container truck transporting a container in a container terminal, while Figure 3.8 illustrates a truck without an attached trailer, known as a bobtail. These are typical of trucks in use at Authority marine terminals and are provided for illustrative purposes.
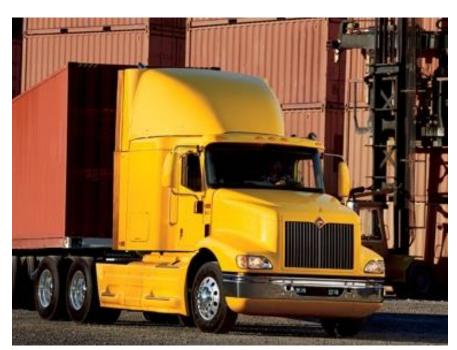
Figure 3.7: HDV with Container

Figure 3.8: HDV - Bobtail

SECTION 4: LOCOMOTIVES

This section presents estimated emissions from the locomotives that visit and serve the Authority's marine container terminals and discusses the methodologies used in developing the estimates. For developing the emissions estimates, locomotive activity has been considered in two general categories, line haul and switching activity. Line haul activity refers to the movement of import and export cargo from and to the Authority marine terminals to and from locations outside the boundary of the Authority facilities but within the NYNJLINA, or to and from the boundary of the NYNJLINA for trains that travel beyond the area. Switching locomotive activity includes activity related to movement of cargo within the boundaries of the following Authority marine terminals:

➢ Port Newark
➢ Elizabeth - Port Authority Marine Terminal
➢ Port Jersey - Port Authority Marine Terminal
➢ Howland Hook Marine Terminal
➢ ExpressRail at Howland Hook, Staten Island

In addition to this switching activity, one container terminal operates a single switching locomotive to move rail cars on their terminal. In addition, the Authority-owned New York New Jersey Rail, LLC (NYNJR) operates a cross-harbor carfloat service that uses switching locomotives to move rail cars off of and onto a barge with rail track on its deck that runs between the Greenville Yard in Jersey City (in Hudson Co., NJ) and the 65th St. Yard in Brooklyn (in Kings Co., NY). These switching operations are also included in the emission estimates. This section consists of the following subsections:

➢ 4.1 - Locomotive Emission Estimates
➢ 4.2 - Locomotive Emission Comparisons
➢ 4.3 - Locomotive Emission Calculation methodology
➢ 4.4 - Description of Locomotives

4.1 Locomotive Emission Estimates

This subsection presents the estimated emissions from line haul and switching activities associated with the Authority marine terminals. The relationships between these emissions and overall county and state emissions are presented and discussed in subsection 4.2. Table 4.1 summarizes the line haul and switching emissions.

Table 4.1: Locomotive Emission Estimates, tpy

Locomotive Type	NOx	PM10	PM2.5	VOC	CO	SO2	CO2e
			tons per year				
Line Haul	118	2.8	2.5	4.3	33.5	0.1	12,910
Switching	209	9.0	8.3	21.0	40	0.2	14,781
Totals	**327**	**11.7**	**10.8**	**25**	**73**	**0.3**	**27,691**

4.2 Locomotive Emission Comparisons

This subsection presents locomotive emission estimates in the context of county-wide and non-attainment area-wide emissions and presents a comparison of 2021 locomotive emissions with the results of earlier emissions inventories.

4.2.1 Comparisons with County and Regional Emissions
Table 4.2 presents the estimated locomotive criteria pollutant and GHG emissions in the context of overall emissions in the states of New York and New Jersey, and in the NYNJLINA, including emissions in tons per year and the percentage that PANYNJ locomotive emissions make up of overall NYNJLINA emissions.[16]

Table 4.2: Comparison of PANYNJ Marine Terminals Locomotive Emissions with State and NYNJLINA Emissions, tpy

Geographical Extent / Source Category	NOx	PM10	PM2.5	VOC	CO	SO2	CO2e
			tons per year				
New York and New Jersey	391,399	243,410	88,019	839,013	2,184,903	30,760	200,748,788
NYNJLINA	195,448	70,552	31,889	252,955	1,011,780	8,568	106,102,779
Locomotives	327	12	11	25	73	0.3	27,691
% of NYNJLINA Emissi	**0.17%**	**0.02%**	**0.03%**	**0.01%**	**0.01%**	**0.004%**	**0.03%**

Authority marine terminal-related locomotive emissions are compared with all emissions in the NYNJLINA counties on a county-by-county basis. Overall county-level emissions were excerpted from the most recent National Emissions Inventory database.[17] Line haul locomotive activity is apportioned to the county level through a determination of the percentage of railroad track transiting individual counties vs. the regional track length. Emissions were calculated for rail trips at the county level and were summed to yield the regional total. A more detailed discussion of the rail emission calculation methodology is presented in subsection 4.3.

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[16] 2017 National Emission Inventory Databases, US EPA, as cited above.

[17] Accessed at: *https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data*

Table 4.3 presents estimated criteria pollutant emissions from the Authority marine terminal-related locomotive activity reported in this current inventory, at the county level.

Table 4.3: Summary of Locomotive Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
				tons per year				
Bergen	NJ	22.4	0.5	0.5	0.8	6.4	0.0	2,455
Essex	NJ	128.8	5.4	5.0	12.4	25.0	0.1	9,303
Hudson	NJ	33.7	1.0	0.9	2.0	8.5	0.0	3,209
Middlesex	NJ	7.1	0.2	0.2	0.3	2.0	0.0	782
Monmouth	NJ	0.0	0.0	0.0	0.0	0.0	0.0	0
Union	NJ	74.4	2.8	2.6	6.2	15.9	0.1	5,981
New Jersey subtotal		**266**	**9.9**	**9.1**	**22**	**58**	**0.3**	**21,730**
Bronx	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Kings (Brooklyn)	NY	0.7	0.0	0.0	0.0	0.3	0.0	104
Nassau	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
New York	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Orange	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Queens	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Richmond (Staten Is	NY	23.7	1.0	0.9	2.4	5.2	0.0	1,928
Rockland	NY	35.9	0.8	0.8	1.3	10.2	0.0	3,928
Suffolk	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
Westchester	NY	0.0	0.0	0.0	0.0	0.0	0.0	0
New York subtotal		**60**	**1.8**	**1.7**	**3.7**	**16**	**0.1**	**5,960**
Total		**327**	**11.7**	**10.8**	**25**	**73**	**0.3**	**27,691**

The following figure illustrates the PANYNJ marine terminals percentage of locomotive emissions contribution in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure 4.1: PANYNJ Marine Terminals Locomotive Percent Contribution to Local Air Emissions

4.2.2 Comparisons with Prior Year Emission Estimates

Emissions were almost unchanged between 2020 and 2021, with 2% increases of CO and CO_2e and a one-ton decrease of NOx, while there was a 0.5% increase in on-dock rail lifts during the same period. Between 2006 and 2021, with the exception of SO_2, the locomotive emissions increased but at a lower rate than the increase in cargo moved by rail into and out of the Port. The pollutants NO_x and PM increased 14% and 15%, respectively, compared to the 109% increase in the number of on-dock lifts. The SO_2 emissions are significantly lower (2006 to 2021) due to the use of lower sulfur fuel. The on-dock rail throughput more than doubled between 2006 and 2021 but the increases in CO and CO_2 were lower, at 67% and 88%, respectively, likely due to incremental efficiency improvements implemented by the railroads and the Authority.
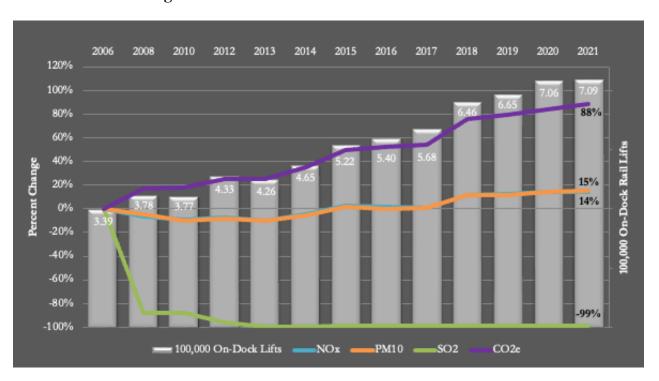
Table 4.4 presents the 2021 locomotive emissions, along with the previous year and 2006 locomotive emissions.

Table 4.4: Locomotive Emissions Comparison, tpy and %

Inventory Year	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons	On-dock Lifts
2021	327	12	11	25	73	0.3	27,691	709,094
2020	328	12	11	25	72	0.3	27,087	705,895
2006	286	10	9	20	44	32	14,710	338,884
2020-2021, Change (%)	**0%**	**0%**	**0%**	**0%**	**2%**	**0.0%**	**2%**	**0%**
2006-2021, Change (%)	**14%**	**15%**	**15%**	**27%**	**67%**	**-99%**	**88%**	**109%**

The following figure graphically illustrates the changes in locomotive emissions of NO_x, PM_{10}, SO_2 and CO_2 between the 2006 baseline emissions inventory and the 2021 update, with emission trend lines superimposed over the annual on-dock lift throughput (in thousands of lifts). The NO_x and PM_{10} emission changes track closely together and may be hard to distinguish from one another in the figure. The NO_x and PM_{10} emissions are 14% and 15% higher, respectively, in 2021 than in 2006.

Figure 4.2: Locomotive Emissions Relative to On-dock Lifts

4.3 Locomotive Emission Calculation Methodology

There is no regulatory model available for estimating locomotive emissions, such as the MOVES3b model used for CHE and HDVs; therefore, emissions from locomotives have been estimated using emission factors published by EPA and activity data obtained from the Port. The following subsections detail the methodology used to develop line haul and switching emission estimates.

4.3.1 Line Haul Emissions

The information obtained regarding line haul rail service includes the total number of containers moved into and out of the Authority's marine terminals via rail,[18] the rail line routes used to transport these goods, an approximate schedule for these trains, and the average length of primary scheduled trains. This data has been used to estimate the total amount of fuel used by the locomotives and hence the associated emissions.

The basis of the line haul emission estimates is the estimated amount of fuel used in the transport of cargo to and from the Authority marine terminals, which has been estimated using several parameters including the number of train trips, estimated train weights, and distance. Step one in this process estimates the number and average lengths and container capacities of trains used to transport this cargo. Step two estimates the average weight of each of these trains (gross tons, the weight of cargo and rail cars); the final calculation of emissions from these trains is based on multiplying the weight moved by the distance over which the trains traveled, and multiplying the resulting estimate of gross ton-miles (GTM) by a conversion factor to estimate gallons of fuel and by fuel-based emission factors expressed as grams of emissions per gallon of fuel (g/gal). The process is explained in detail below.

The emission factors for most pollutants (NO_x, PM, VOCs, CO) come from an EPA publication[19] issued in support of locomotive rulemaking. The emission factors are published for each engine tier level and also (for NO_x, PM, and VOCs) for annual fleet composites representing EPA's projection of fleet turnover and the makeup of the nationwide locomotive fleet annually through calendar year 2040. The fleet composite emission factors for calendar year 2021 have been used in this emissions inventory instead of the tier-specific emission factors because information on the tier levels of the locomotives calling at the Port during 2021 is not available. The annual composite emission factors are published as fuel-based factors in units of grams of pollutant per gallon of fuel (g/gal). The emission factor for CO remains constant across tier levels and is published as g/hp-hr, while emission factors for SO_2 and CO_2 have been developed using a mass balance approach based on the typical amounts of sulfur and carbon in diesel fuel. The SO_2 emission factor assumes diesel fuel sulfur content of 15 ppm in 2021. The emission factors for N_2O and CH_4 were obtained from an EPA publication on greenhouse gases.[20]

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[18] Information provided by PANYNJ by email 29 August and 6 September 2022.

[19] "Emission Factors for Locomotives," EPA-420-F-09-025, Office of Transportation and Air Quality, April 2009

[20] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2019; April 2021; Table A- 114: Emission Factors for N_2O Emissions from Non-Highway Mobile Combustion (g gas/kg fuel) and Table A- 115: Emission Factors for CH_4 Emissions from Non-Highway Mobile Combustion (g gas/kg fuel).

The emission factors for line haul locomotives are presented in Table 4.5. The published g/gal emission factors for 2021 are listed as well as energy-based emission factors in grams per horsepower-hour (g/hp-hr) that have been converted from the fuel-based emission factors using a conversion factor of 20.8 horsepower-hours per gallon of fuel, published in the same EPA document cited above.

Table 4.5: Line-Haul Locomotive Emission Factors

Units	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2	N_2O	CH_4
g/gal	94	2.2	2.0	3.4	26.7	0.10	10,186	0.25	0.79
g/hp-hr	4.5	0.11	0.10	0.16	1.28	0.005	489	0.012	0.038

The starting point of the calculations is the average length and schedule of trains servicing each marine terminal, as reported in the 2005 Authority rail utilization study.[21] Each of the two railroads serving the marine terminals operates one inbound and two outbound trains per day. The inbound trains are transporting export cargo to be loaded onto ships while the outbound trains are transporting imports that have been brought to the port on ships. Because the balance of trade favors imports, there is a need for the additional outbound train. The estimating process involves balancing the annual number and average capacity of the scheduled trains with the total number of containers moved by rail during the year. The first step is to estimate the average lengths of the trains based on how many rail cars they are made up of, using the following equation.

Train length
= Number of cars × Car length × Number of locomotives
× Locomotive length

Where:
> Train length = Estimated length of intermodal train, feet
> Number of cars = Number of multi-platform rail cars per train
> Car length = Length of each 5-platform car, feet
> Number of locomotives = Average number of locomotives per train
> Locomotive length = Length of each locomotive, feet

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[21] Port Authority of NY&NJ, *New Jersey Marine Terminal Rail Facility 2005 Comparison Study*, CH2MHILL, February 2006.

Table 4.6 presents the parameters and estimated average lengths of the inbound and outbound trains of both railroads, with three columns representing each railroad.

Table 4.6: Line-Haul Train Length Assumptions

Parameters	Trains - Railroad "A"			Trains - Railroad "B"		
	Outbound	Outbound	Inbound	Outbound	Outbound	Inbound
# of 5-platform cars per train	30	30	30	30	30	26
Length of 5-platform car, feet	300	300	300	300	300	300
Length of cargo, feet	9,000	9,000	9,000	9,000	9,000	7,800
Length of 1 locomotive, feet	70	70	70	70	70	70
# of locomotives per train	2	2	2	2	2	2
Total locomotive length, feet	140	140	140	140	140	140
Total train length	**9,140**	**9,140**	**9,140**	**9,140**	**9,140**	**7,940**

In addition to train length, the average number of containers each train can carry is estimated using the following equation.

Train capacity
$$= \textbf{\textit{Number of cars}} \times \textbf{\textit{Number of platforms/car}} \times \textbf{\textit{TEUs/platform}} \times \textbf{\textit{Density}} \times \textbf{\textit{TEUs/container}}$$

Where:

Train capacity = Estimated number of containers per train
Number of cars = Number of multi-platform rail cars per train
Number of platforms/car = Number of platforms per rail car
TEUs/platform = Maximum number of TEUs per platform
Density = average percentage utilization of platforms
TEUs/container = Average number of TEUs per container

Table 4.7 shows the estimated number of containers each average train would carry, based on 5-platform railcars, each platform capable of holding up to four TEUs (maximum load consisting of two 40-ft containers). In this table, the potential number of TEUs per train is estimated by multiplying the number of cars per train shown in the previous table by the number of platforms per car and the capacity number of TEUs per platform. Not all platforms may be filled with 4 TEUs, however, and the term "density" is used to describe the percentage of potential capacity that is actually filled. The density assumptions are shown in Table 4.7, with 100% density meaning all container slots are assumed to be filled. Multiplying the potential TEU capacity of the train by the density value estimates the actual TEU content of the typical train and dividing by the average number of TEUs per container (most, but not all, containers are 40 feet, so the average is less than 2) estimates the number of containers that can be carried by the train sizes shown in the table.

Table 4.7: Line-Haul Train Container Capacities

Parameters	Trains - Railroad "A"			Trains - Railroad "B"		
	Outbound	Outbound	Inbound	Outbound	Outbound	Inbound
Platforms/car	5	5	5	5	5	5
TEUs/platform (capacity)	4	4	4	4	4	4
TEUs per train (potential)	600	600	600	600	600	520
Average "density"	100%	100%	100%	100%	100%	100%
TEUs per train (adjusted)	600	600	600	600	600	520
Average TEUs per container:	1.80	1.80	1.80	1.80	1.80	1.80
Containers per train (average)	**333**	**333**	**333**	**333**	**333**	**288**

The total number of containers moved by rail during the year is estimated using the following equation.

$$Total\ containers = Trains/day \times Days/week \times Containers/train$$

Where:

       Total containers = Estimated number of containers moved by train
       Trains/day = Average number of trains each day
       Days/week = Average number of days each week in which a train arrives or departs
       Containers/train = Estimated train capacity, average number of containers per train

Table 4.8 lists the train schedule assumptions, most of which are described in the rail utilization study. The secondary train schedule assumptions have been chosen to balance the total container throughputs estimated using the methods described in these paragraphs with the actual reported throughputs. The annual number of containers estimated for each railroad is the product of the number of trains per day, the days per week those trains run, and the number of containers each train can carry (from Table 4.7). The total estimated number of containers moved by the train configurations described above (and shown below in Table 4.8) corresponds to the reported actual 2021 on-dock rail throughput to within approximately one quarter of a percent (estimated total of 363,636 + 347,256 = 710,892, versus actual 709,094). While not exact, the degree of correspondence between estimated and reported throughput provides a degree of confidence in the estimated train parameters on which the emission estimates are based.

Table 4.8: Line-Haul Train Schedules and Throughput

Parameters	Trains - Railroad "A"			Trains - Railroad "B"		
	Outbound	Outbound	Inbound	Outbound	Outbound	Inbound
Trains/day	1	1	1	1	1	1
Days/week	7	7	7	7	7	7
Trains per year	364	364	364	364	364	364
Containers/year	121,212	121,212	121,212	121,212	121,212	104,832
Total estimated containers:	**363,636**			**347,256**		

The next step in estimating fuel consumption is estimating the gross weight of each of the train sizes described by the previous tables using the following equations.

Train weight
= *Number of cars × Number of platforms/car × Gross tons/platform*

Where:
> Train weight = Estimated weight of average train, tons
> Number of cars = Number of multi-platform rail cars per train
> Number of platforms/cars = Number of platforms per rail car
> Gross tons/platform = Average weight of platform with cargo, tons

Information for these estimates was obtained from reports submitted by the Norfolk Southern and CSX railroads to the U.S. Surface Transportation Board in the 2021 submittals of an annual report known as the "R-1."[22] Among the details in this report are the total gross ton-miles moved by locomotives in freight service and the total freight moved in railcar-miles. The term "railcar" as listed in the R-1 reports is analogous to a "platform" as described in this report rather than the 5-platform railcar commonly used in container service. Dividing gross ton-miles by railcar-miles provides an estimate of the average weight of a railcar (platform) in normal service (gross ton-miles/railcar-miles = gross tons/railcar). The average platform weight estimated in this manner is shown in Table 4.9. In addition to average platform weight, Table 4.9 lists the average number of platforms per train, estimated by multiplying the number of 5-platom cars by 5. The average gross weight of each train type is the number of railcars multiplied by the average gross weight per platform, as shown in Table 4.9.

Table 4.9: Line-Haul Train Gross Weight

Parameters	Trains - Railroad "A"			Trains - Railroad "B"		
	Outbound	Outbound	Inbound	Outbound	Outbound	Inbound
Platforms per train (average)	150	150	150	150	150	130
Gross tons per platform	90	90	90	90	90	90
Gross weight of train	**13,494**	**13,494**	**13,494**	**13,494**	**13,494**	**11,695**

Overall annual gross tonnage for each railroad is the gross weight of each train multiplied by the number of trains per year. These figures total approximately **14.74 million gross tons** for the railroad whose trains are represented by the left three columns in the previous tables, and approximately **14.08 million gross tons** for the railroad whose trains are represented by the three columns to the right.

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[22] *Class I Railroad Annual Report to the Surface Transportation Board for the Year Ending Dec. 31, 2021* (Norfolk Southern Railroad) and *Class I Railroad Annual Report to the Surface Transportation Board for the Year Ending Dec. 31, 2021* (CSX Transportation, Inc.). *https://www.stb.gov/stb/industry/econ_reports.html*

Since fuel use and emissions depend not only on the weight of the trains but also on the distance the trains travel, the primary routes taken by the two railroads were evaluated for distance within each county included in this inventory, and the annual number of gross tons for each railroad was multiplied by the distance. The result of this calculation is an estimate of the number of gross ton-miles associated with each county, as shown in Table 4.10. Fuel consumption in each county was estimated by multiplying the ton-miles by the factor of 0.98 gallons of fuel per thousand gross ton-miles, derived from information in the 2021 R-1 reports on fuel consumption and gross ton-miles. The result of this calculation step is also shown in the table below.

Table 4.10: Line Haul Locomotive Ton-Mile and Fuel Use Estimates

County	Track Mileage	Thousand Gross Ton-Miles	Gallons Fuel
North Route			
Essex	3	44,207,263	43,323
Hudson	13	191,564,805	187,734
Bergen	15	221,036,313	216,616
Rockland	24	353,658,101	346,585
South Route			
Essex	5	70,404,159	68,996
Union	15	211,212,477	206,988
Middlesex	5	70,404,159	68,996
Total	**80**	**1,162,487,277**	**1,139,238**

The last step is to apply the emission factors (Table 4.5) in grams per gallon to the fuel use estimate (in gallons) presented above to calculate the total line haul locomotive emissions.

4.3.2 Switching Emissions
Switching emission estimates have been based primarily on the activity information developed for the previous Authority inventories of CHE and rail emissions, and the change in on-rail cargo throughputs at Port Newark, Elizabeth PA Marine Terminal, Staten Island, and Bayonne between 2020 and 2021. The scaling of activity with growth in container throughput by rail should provide a reasonable estimate of activity growth. The 2002 emission estimates were based on the number and duration of daily shift operations, and the later estimates have been made using the ratios of container throughputs by rail. For example, 709,000 containers moved by rail in 2021 divided by 706,000 containers moved by rail in 2020 results in a growth factor of 1.004 or a 0.04% increase in throughput; this was multiplied by the 2020 operating hours estimate of 71,348 for a 2021 estimate of 71,633 hours.

A variety of switchers operate in ExpressRail service, a network of dedicated rail facilities including support track and rail yards for each of the port's major container terminals. These include ultra-low emission locomotives powered by two or three generator sets (genset locomotives) rather than one large locomotive engine. These genset locomotives emit lower levels of most pollutants than typical switchers and have been estimated to reduce particulate emissions within the NYNJLINA by as much as 3.22 tons per year and NO_x emissions by as much as 64.0 tons per year compared with the locomotives they replaced.[23] While these reductions have been projected for the non-attainment area as a whole, operational information has not been available to differentiate the reductions that have been achieved within the Port domain of this emissions inventory.

Estimates of locomotive engine emissions are based on their regulatory "Tier level," which is based on when they were built or rebuilt. The ExpressRail switchers are assumed to emit at an average of Tier 1 rates, which are applicable to locomotives built between approximately 2002 and 2004. Older locomotives emit higher rates of most pollutants, while newer locomotives, including the low-emission replacement locomotives discussed above, emit at lower rates. In the absence of specific information on how much work each type of locomotive performed within the inventory domain, the Tier 1 rates represent a reasonably conservative approach to estimating overall switching emissions and probably over-estimate actual emissions. Emission factors for most pollutants are from the 2009 EPA publication cited above. Emission factors for SO_2 and CO_2 have been developed using a mass balance approach (based on the typical amounts of sulfur and carbon in diesel fuel) and emission factors for N_2O and CH_4 were obtained from the EPA publication on greenhouse gases cited previously. The emission factors are listed in Table 4.11. The switching locomotives operated by the rail-to-barge cross-harbor service are new Tier 4i units. The container terminal that operates a single switcher on terminal has also upgraded their locomotive to a Tier 4 engine, so the Tier 4 emission factors have been used for that locomotive's emissions.

Table 4.11: Switching Locomotive Emission Factors

Units	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2	N_2O	CH_4
Tier 1 emission factors									
g/gal	150	6.5	6.1	15.3	27.7	0.10	10,182	0.258	0.76
g/hp-hr	9.9	0.43	0.40	1.01	1.83	0.01	672	0.017	0.05
Tier 4i emission factors									
g/gal	68	0.2	0.2	1.2	27.7	0.10	10,182	0.26	0.76
g/hp-hr	4.5	0.015	0.015	0.08	1.83	0.01	672	0.017	0.05
Tier 4 emission factors									
g/gal	15	0.2	0.2	1.2	27.7	0.15	10,182	0.26	0.76
g/hp-hr	1.0	0.015	0.015	0.08	1.83	0.01	672	0.017	0.05

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[23] M.J. Bradley & Associates, LLC. *Reducing Emissions from Diesel Locomotives CSXT / NESCAUM - DPF Genset Locomotive Pilot Project.* October 8, 2010 and M.J. Bradley & Associates, LLC. *CSXT, NJTPA, NJDOT and PANYNJ - Congestion Mitigation and Air Quality - Diesel Emission Reduction Project - Locomotive Repower Project Oak Island — Newark, NJ.* May 2012.

The emission factors are expressed in units of grams per horsepower-hour. An estimate of annual horsepower-hours was developed from the adjusted operating hour estimate discussed above using data contained in an EPA dataset that lists average switching duty in-use horsepower for 20 locomotive models rated between 1,500 and 4,100 horsepower, averaging 3,030 horsepower. The in-use horsepower in this dataset varies from 159 to 349 horsepower, with an average of 264 horsepower. Multiplying the estimate of 71,633 hours by the average in-use horsepower of 264 results in an estimate of approximately 18.9 million horsepower-hours for the year. The emission factors were multiplied by this total to estimate annual switching emissions. For the container terminal switching locomotive the horsepower-hours were estimated from the reported number of operating hours multiplied by the average in-use horsepower. The horsepower-hours of the rail-to-barge cross-harbor service switchers were estimated by converting the annual fuel consumption (in gallons) of these locomotives to horsepower-hours using a brake-specific fuel consumption factor, which represents the number of gallons of fuel consumed per horsepower-hour.

4.4 Description of Locomotives

This subsection describes the rail system as it served the Authority marine terminals in 2021 and the locomotives that were in service.

4.4.1 Operational Modes

Locomotives are used in two general modes of operation, terminal switching and line haul. Switching activities take place within a limited geographical area and are the activities related to preparing trains for transport to distant locations and to breaking up and distributing railcars from trains arriving from distant origins. Line haul refers to the movement of rail freight over long distances, between local rail yards and distant locations.

The rail activities associated with the Authority marine terminals covered by this 2021 emissions inventory consist primarily of intermodal (containerized cargo) service associated with the container terminals at Port Newark and the Elizabeth PA Marine Terminal (i.e., Port Newark Container Terminal, Maher Terminal, APM Terminal), at the Howland Hook Marine Terminal on Staten Island, New York, operated by Global Container Terminal – New York, and at the Global Container Terminal – Bayonne terminal. Switching takes place adjacent to the Port Newark Container Terminal (an operation known as ExpressRail Port Newark), at a rail facility between the APM and Maher Terminals (known as ExpressRail Elizabeth), and at the New York Container Terminal at Howland Hook (ExpressRail Staten Island). ExpressRail is operated by Consolidated Rail Corporation (Conrail), a jointly owned, private subsidiary of the Norfolk Southern and CSX Railroads, using switching locomotives owned by either Norfolk Southern or CSX. These switchers are used within an area known as the Northern New Jersey Shared Asset Area, which includes rail yards other than those associated with the Authority. It is this joint use of switching locomotives that makes it difficult to determine the effect of the use of low-emission locomotives at the Authority facilities specifically.

Beyond the Authority marine terminals, container trains are transported to and from ExpressRail by Norfolk Southern and CSX. The primary route for CSX is north/south parallel to the Hudson River, while Norfolk Southern trains run east/west. Approximately 55 miles of the CSX route is within the counties covered by this emissions inventory, while the Norfolk Southern route includes approximately 25 miles within the area.

4.4.2 Locomotives

The locomotives used in these activities are essentially similar, although switching locomotives are usually smaller than the locomotives used in line haul service. Locomotives in switching service, except for the genset switchers, are often older line haul locomotives that are no longer suitable for the longer and heavier trains that are common in present-day train transport. Line haul locomotives, especially those in intermodal service (used in transporting containerized cargo) are typically larger than 4,000 horsepower, while locomotives in switching use are smaller, typically under 3,000 horsepower.

Locomotives operate somewhat differently than other types of land-based mobile sources in that their engines are not directly coupled to their wheels via a transmission and drive shaft; instead, the locomotive engine powers a generator or alternator that generates electricity which, in turn, powers an electric motor that turns the drive wheels. This method of operation means that locomotive engines operate under more steady-state operating conditions than more typical mobile source engines, which undergo frequent changes in speed and load during normal operation. By contrast, locomotives have been designed to operate in a series of discrete throttle positions, called notches, typically one through eight plus an idle position. Many locomotives also have an operating condition known as dynamic braking, in which the electric engine operates as a generator to help slow the train, with the generated power being dissipated as heat.

Because line haul locomotives are used to transport cargo across large areas of the country, they are dispatched by the railroads that own and operate them on the basis of where they are needed and not on the basis of any discrete operating area. Therefore, there are no "local fleets" of line haul locomotives. To a large extent this is also true of switching locomotives, which can be moved among several rail yards in the area, most of which are not directly associated with Authority marine terminals. For this reason, the emission estimates discussed in the previous subsections are based on activity patterns and general locomotive and train characteristics rather than locomotive-specific information.

Figure 4.3: Example Switching Locomotives at On-Dock Rail Facility

Photo courtesy of PANYNJ

Figure 4.4: Example Switching Locomotive

Photo courtesy of PANYNJ

Figure 4.5: Example Line Haul Locomotive

Photo courtesy of PANYNJ

SECTION 5: COMMERCIAL MARINE VESSELS

This section presents estimated emissions from ocean-going vessels (OGVs) and harbor craft, collectively known as commercial marine vessels (CMVs), calling at the following Authority marine terminals.

- ➢ Port Newark
- ➢ Elizabeth-Port Authority Marine Terminal
- ➢ Port Jersey-Port Authority Marine Terminal
- ➢ Howland Hook Marine Terminal
- ➢ Brooklyn-Port Authority Marine Terminal

The berths at these marine terminals handle many cargoes, such as containers, cruise passengers, automobiles, bulk liquids, and break bulk. Thus, this category includes a wide variety of OGV types along with assist tugs and barges.

The Port of New York and New Jersey also includes many marine terminals that are privately owned and operated, which do not come under the aegis of the Authority, such as the various fuel and oil depots situated along the Arthur Kill/Kill Van Kull waterways. The emissions from vessels calling at these terminals are not included in this inventory.

The geographic area covered by this inventory remains unchanged from the commercial marine vessel emissions inventories developed for prior years. It includes the counties within the NYNJLINA in which Authority marine terminal-related CMV activity occurs, and is bounded on the ocean side by the three-nautical-mile demarcation line off the eastern coast of the U.S. This line, shown in Figure 5.1, is also the boundary of the New York New Jersey Harbor System (NYNJHS), as designated by the U.S. Army Corps of Engineers. The NYNJHS encompasses the predominant CMV activity area within the region. The counties within this area that include marine vessel activity are the New York counties Bronx, Kings, Queens, Richmond, Nassau, New York, Orange, Rockland, Suffolk, Westchester; and the New Jersey counties Bergen, Monmouth, Ocean, Middlesex, Hudson, Essex, and Union. However, Ocean County, New Jersey, has not been included with the NYNJLINA counties listed in various tables in this report because no identified Authority marine terminal related CMV activities or emissions occur within the county.

In many cases, vessel travel lanes do not fall neatly within one or another county. Best efforts have been made to reasonably allocate emissions to the relevant counties (and states).

This section consists of the following subsections:

- ➢ 5.1 - CMV Emission Estimates
- ➢ 5.2 - CMV Emission Comparisons
- ➢ 5.3 - CMV Emission Calculation Methodology
- ➢ 5.4 - Description of CMV and Vessel Activity

5.1 CMV Emission Estimates

Emission estimates have been developed for CMV on the basis of vessel type, engine type and relative activity. The following OGV types are included: containerships, cruise ships, automobile and other vehicle carriers, tankers, and bulk carriers. The harbor craft category includes vessels that assist ocean-going vessels in maneuvering and docking (assist tugs) and the vessels that move cargo barges within the NYNJHS (towboats). Emissions from barges are not included because the inventory is limited to mobile source combustion emissions. Emissions have been estimated for OGV and harbor craft main engines, which provide propulsion power; auxiliary engines, which run electrical generators for auxiliary vessel power; and auxiliary boilers, which provide heat for fuel treatment and other on-board uses in OGV. Harbor craft are not equipped with boilers.

Figure 5.1 illustrates the outer limit of the study area on the ocean side for all commercial marine vessels and the typical routes taken by OGVs traveling to the terminals covered by this inventory. The outer limit is three nautical miles (nm) beyond the line indicated on the figure as the Territorial Sea Line, off the eastern coast of the U.S.
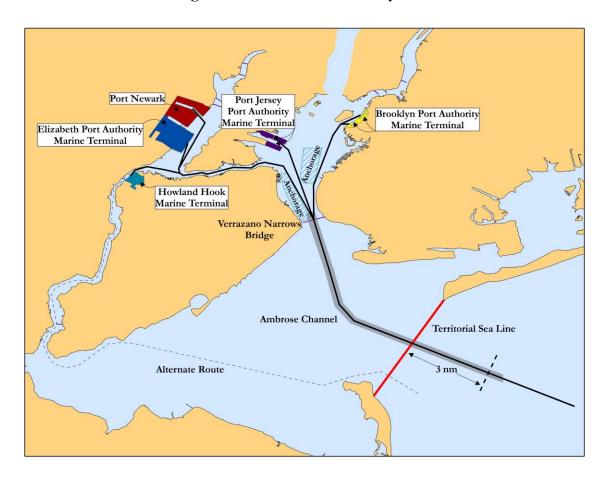
Figure 5.1: Outer Limit of Study Area

Vessels occasionally wait for berth space while anchored in one of two designated anchorage areas located in the harbor within the Verrazano Narrows Bridge. Emissions from vessels that are at anchorage in one of these areas are included in the total emissions presented in this report. During 2021, vessels may also have waited at anchor while offshore, outside the three nm limit of this EI's domain. However, such anchorage activity, if it occurred, has not been included in the emissions estimated for this inventory. Data available to the Authority suggest that this remote anchorage activity occurred primarily in 2022.

The following tables present the estimated OGV emissions in several different aspects. Table 5.1 lists the emissions from OGVs by vessel type. The containership and tankers emissions are shown by subcategories. The numbers associated with the containership subcategories refer to size ranges in TEU capacity.

Table 5.1: OGV Emissions by Vessel Type, tpy

Vessel Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Auto Carrier	195	3.3	3.1	8.5	19.7	5.3	14,026
Bulk Carrier	86	1.7	1.6	3.0	8.2	4.0	6,906
Container - 1000	69	1.8	1.6	2.9	7.8	4.2	7,594
Container - 2000	82	1.4	1.3	3.5	8.0	2.7	5,848
Container - 3000	34	0.6	0.5	1.3	3.1	1.1	2,643
Container - 4000	198	3.4	3.1	10.7	20.5	6.4	13,168
Container - 5000	75	1.2	1.1	4.1	7.7	1.9	4,961
Container - 6000	331	6.0	5.5	25.1	41.2	9.9	20,905
Container - 7000	26	0.5	0.4	1.6	2.8	0.6	2,008
Container - 8000	546	9.2	8.5	24.8	51.3	14.3	39,760
Container - 9000	151	2.7	2.5	7.7	15.6	3.7	11,753
Container - 10000	46	0.8	0.7	2.2	4.6	1.1	3,369
Container - 11000	106	2.1	1.9	9.0	14.5	2.5	7,709
Container - 12000	19	0.5	0.5	2.1	3.8	0.5	2,191
Container - 13000	235	4.6	4.3	10.5	23.4	5.9	21,440
Container - 14000	81	1.6	1.5	3.8	8.8	2.2	6,981
Container - 15000	17	0.3	0.3	0.6	1.6	0.7	1,430
Container - 16000	6	0.1	0.1	0.5	0.9	0.3	510
Cruise Ship	78	1.4	1.3	2.8	7.5	3.2	5,390
General Cargo	30	0.6	0.6	1.2	3.1	1.4	2,543
RoRo	41	0.7	0.6	2.3	4.7	0.7	2,864
Tanker	87	1.8	1.6	3.3	8.6	4.2	7,107
Total	**2,537**	**46**	**43**	**131**	**267**	**77**	**191,104**

Table 5.2 presents the OGV emissions by engine type. Table 5.3 differentiates emissions according to transit and dwelling (hoteling) activity.

Table 5.2: OGV Emissions by Emission Source Type, tpy

Emission Source Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Main Engines	903	9	9	67	94	12	29,532
Auxiliary Engines	1,517	26	24	59	161	42	103,375
Boilers	117	11	10	6	12	23	58,197
Total	**2,537**	**46**	**43**	**131**	**267**	**77**	**191,104**

Table 5.3: OGV Emissions by Operating Mode, tpy

Operating Mode	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Transit	1,167	14	13	77	122	20	50,578
Dwelling	1,369	32	29	54	145	56	140,526
Total	**2,537**	**46**	**43**	**131**	**267**	**77**	**191,104**

Table 5.4 presents estimated emissions for tow boats and assist tugs. The towboats/pushboats emissions include the barge call activity at the bulk berths and two container terminals. The assist tugs provide assist and escort services for the ocean-going vessels that call Authority marine terminals.

Table 5.4: Harbor Craft Emissions, tpy

Vessel Type	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Towboats/Pushboats	167	3	3	4	32	0.1	13,082
Assist Tugs	139	3	3	3	47	0.2	22,392
Totals	**307**	**6**	**6**	**6**	**79**	**0.3**	**35,475**

5.2 CMV Emission Comparisons

This subsection presents the CMV emission estimates detailed in Section 5.1 in the context of overall county-wide and area-wide emissions and a comparison of current year emission estimates with the previous years' inventories. First, Authority marine terminal-related OGV and harbor craft emissions are compared with all emissions in the NYNJLINA on a county-by-county basis. Overall county-level emissions were excerpted from the most recent National Emissions Inventory (2017 NEI). These emission comparisons are segregated into OGV and harbor craft categories and are presented in subsections 5.2.1 and 5.2.2 respectively. Subsection 5.2.3 presents 2021 OGV and harbor craft emission estimates in comparison with previous year emission estimates to illustrate the changes in emissions over time.

Table 5.5 presents the estimated CMV emissions in the context of overall emissions in the states of New York and New Jersey, and in the NYNJLINA, including emissions in tons per year and the percentage that PANYNJ CMV emissions make up of overall NYNJLINA emissions.

Table 5.5: Comparison of PANYNJ Marine Terminals CMV Emissions with State and NYNJLINA Emissions, tpy

Geographical Extent / Source Category	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
NY and NJ	391,399	243,410	88,019	839,013	2,184,903	30,760	200,748,788
NYNJLINA	195,448	70,552	31,889	252,955	1,011,780	8,568	106,102,779
OGV	2,537	46	43	131	267	77	191,104
Harbor Craft	307	6	6	6	79	0.3	35,475
Total Commercial Marine Vessels	2,843	53	49	138	347	77	226,578
% of NYNJLINA Emissions	**1.5%**	**0.07%**	**0.15%**	**0.05%**	**0.03%**	**0.9%**	**0.2%**

5.2.1 OGV Emission Comparisons with County and Regional Emissions
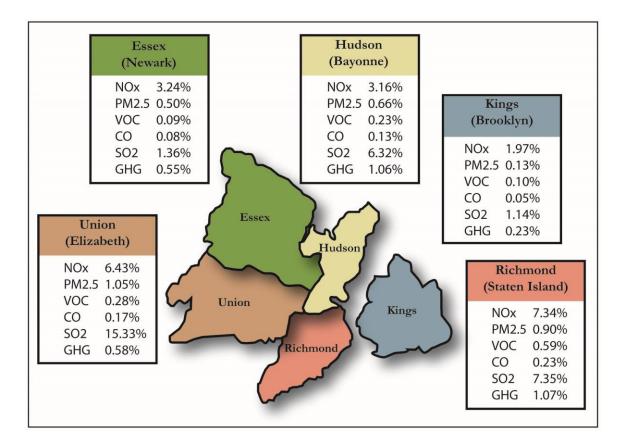
Table 5.6 summarizes estimated criteria pollutant and GHG emissions from OGVs at the county level. All counties within the inventory area are listed, so counties without associated OGV emissions are shown with zero emissions. The percentage allocation of emissions per county are based on the geographical location of Automatic Identification System (AIS) data points provided by the U.S. Coast Guard, so the allocation percentages may change from year to year along with the activity.

Table 5.6: Summary of PANYNJ Marine Terminals OGV Emissions by County, tpy

County	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Bergen	0	0	0	0	0	0	0
Essex	540	11	10	23	56	20	48,492
Hudson	314	6	6	18	35	9	24,452
Middlesex	0	0	0	0	0	0	1
Monmouth	256	3	2	11	23	4	10,574
Union	594	15	14	25	65	27	65,586
New Jersey subtotal	**1,705**	**35**	**32**	**77**	**179**	**60**	**149,104**
Bronx	0	0	0	0	0	0	0
Kings	267	4	3	17	28	5	12,866
Nassau	0	0	0	0	0	0	0
New York	1	0	0	0	0	0	58
Orange	0	0	0	0	0	0	0
Queens	155	2	1	7	14	3	6,376
Richmond	410	6	6	31	47	9	22,700
Rockland	0	0	0	0	0	0	0
Suffolk	0	0	0	0	0	0	0
Westchester	0	0	0	0	0	0	0
New York subtotal	**832**	**12**	**11**	**54**	**89**	**17**	**41,999**
Total	**2,537**	**46**	**43**	**131**	**267**	**77**	**191,104**

The following figure illustrates the PANYNJ marine terminals percentage of OGV emissions contribution in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure 5.2: PANYNJ Marine Terminals OGV Percent Contribution to Local Air Emissions

5.2.2 Tug and Tow Boat Emission Comparisons with County and Regional Emissions
Table 5.7 summarizes estimated emissions from assist tugs and tow boats at the county level.

Table 5.7: Summary of PANYNJ Marine Terminals Harbor Craft Emissions by County, tpy

County	State	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2e
Bergen	NJ	2	0.0	0.0	0.0	0.3	0.00	126.47
Essex	NJ	60	1.3	1.2	1.2	19.0	0.08	8,891.30
Hudson	NJ	49	1.0	1.0	1.1	11.2	0.04	4,801.45
Middlesex	NJ	11	0.2	0.2	0.3	2.2	0.01	889.96
Monmouth	NJ	8	0.2	0.2	0.2	1.6	0.01	655.76
Union	NJ	78	1.6	1.6	1.5	24.1	0.10	11,235.47
New Jersey subtotal		**208**	**4.3**	**4.2**	**4.3**	**58.4**	**0.23**	**26,600**
Bronx	NY	0	0.0	0.0	0.0	0.1	0.00	23.42
Kings	NY	11	0.2	0.2	0.2	2.7	0.01	1,200.76
Nassau	NY	2	0.0	0.0	0.0	0.4	0.00	168.62
New York	NY	2	0.0	0.0	0.0	0.4	0.00	158.64
Orange	NY	2	0.0	0.0	0.0	0.4	0.00	145.20
Queens	NY	3	0.1	0.1	0.1	0.6	0.00	257.62
Richmond	NY	66	1.3	1.3	1.5	14.1	0.05	5,945.66
Rockland	NY	2	0.0	0.0	0.1	0.4	0.00	177.99
Suffolk	NY	7	0.1	0.1	0.2	1.4	0.01	576.13
Westchester	NY	3	0.1	0.1	0.1	0.5	0.00	220.15
New York subtotal		**98**	**2.0**	**1.9**	**2.2**	**21.1**	**0.08**	**8,874**
TOTAL		**307**	**6.2**	**6.1**	**6.4**	**79.5**	**0.31**	**35,475**

The following figure illustrates the PANYNJ marine terminals percentage of harbor craft emissions contribution in the local counties of Essex, Union, Richmond, Kings, and Hudson.

Figure 5.3: PANYNJ Marine Terminals Harbor Craft Percent Contribution to Local Air Emissions

5.2.3 Comparison of OGV Emissions with Prior Year Emission Estimates

Changes in 2021 OGV emissions and prior years' emissions can be attributed to changing levels of cargo throughput, different vessel types calling the terminals during different years, use of shore power, programs carried out by the Authority to lower emissions, such as the Clean Vessel Incentive Program, and the continued implementation of the North American Emission Control Area (ECA), which mandates lower sulfur fuels within a specified distance of the North American coast.

There is no change to the emission estimating methodology used to calculate 2021 emissions compared to the previous year's inventory. Therefore, the previous year emissions shown in this report remain the same as published in the previous report.

Programs that had an impact on OGV emissions in calendar year 2021 are listed below.

➢ Due to COVID-19, cruise ship calls did not resume until the end of 2021 which resulted in a second year of low activity for cruise ships. Overall, there was a 1% increase in the number of vessel calls for all vessel types in 2021 as compared to 2020.

➢ In June 2017, the Bayonne Bridge Navigational Clearance Project raised the bridge to 215 feet above high mean waters in Kill Van Kull, allowing for the passage of larger vessels. The larger vessels continued to make calls to the terminals in 2021. This was the first year that 16,000 TEU-sized containership called the Port.

➢ All vessels used 0.1% or less sulfur content fuel per the ECA requirement.

➢ The Port Authority of New York and New Jersey CVI Program continued to be in effect in 2021. The CVI program financially rewards operators of OGVs using a formula that includes Vessel Speed Reduction (VSR) points for steaming at 10 knots or less from 20 nm outside of the Territorial Sea Line. Additional points are rewarded to vessels that exceed current international vessel emissions standards represented through the Environmental Ship Index (ESI). In addition, ships enrolled under ESI reported the actual sulfur level of the fuel used which in several instances was lower than the 0.1% sulfur limit under ECA. Enrolled ships also reported their Engine International Air Pollution Prevention (EIAPP) NO_x certificate values for main and auxiliary engines, which demonstrates that these engines emit lower NO_x emissions than the assumed default emission factor. In 2021, 1,751 calls were made to the Authority marine terminals by vessels enrolled in the program, with 354 individual vessels making 955 calls that earned incentive payments.

➢ Newer vessels with Tier III engines are calling the Authority terminals. These vessels comply with IMO Tier III NO_x limits while in US waters which achieve significant NO_x reductions as compared to older engines. However, the full impact of Tier III NOx standards is not achieved if the main engine load is equal or less than 25% because at these loads the exhaust gas temperature does not reach the level required for selective catalytic reduction (SCR) or exhaust gas recirculation (EGR) systems to effectively reduce emissions.

Table 5.8 presents a comparison of 2021 OGV emissions out to the three nautical mile boundary, with emissions in the same area for the previous year and the 2006 baseline year. Compared to 2006, the emissions are lower due to the lower sulfur fuel used to comply with the North American ECA and the CVI program. OGV emissions in 2021 were higher by 11% to 18% (depending on pollutant) compared to 2020, while the TEU throughput increased by 18% and the number of vessels that called the port increased by only 1%. The emission increases were due to the increase in TEU throughput that required more time at berth to unload and unload the larger number of containers.

Table 5.8: OGV Emissions Comparison, tpy and %

Inventory Year	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons	Million TEUs
2021	2,537	46	43	131	267	77	191,104	8.99
2020	2,275	40	37	118	237	65	167,071	7.59
2006	4,165	392	314	185	360	3,681	221,638	5.09
2020-2021, Change (%)	**11%**	**15%**	**15%**	**12%**	**13%**	**18%**	**14%**	**18%**
2006-2021, Change (%)	**-39%**	**-88%**	**-86%**	**-29%**	**-26%**	**-98%**	**-14%**	**76%**

The following figure graphically illustrates the percent change in NO_x, PM_{10}, $PM_{2.5}$, SO_2, and CO_2e emissions from OGVs between the 2006 baseline emissions inventory and the 2021 update, with emission trend lines superimposed over the annual TEU throughput (in millions). The PM_{10} and $PM_{2.5}$ emissions track closely together.
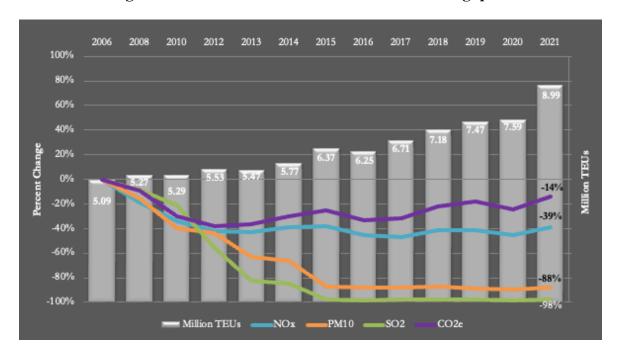
Figure 5.4: OGV Emissions Relative to TEU Throughput

5.2.4 Comparison of Harbor Craft Emissions with Prior Year Emission Estimates
Table 5.9 presents the harbor craft emissions comparison to prior years' emissions. Compared to previous year, overall harbor craft emissions decreased slightly due to the use of newer and more powerful tugboats with Z-drive propulsion systems used to assist and escort the larger vessels. Compared to 2006, the emission reductions are due to fleet turnover to newer vessels.

Table 5.9: Harbor Craft Emissions Comparison, tpy and %

Inventory Year	NO_x tons	PM_{10} tons	$PM_{2.5}$ tons	VOC tons	CO tons	SO_2 tons	CO_2e tons	Million TEUs
2021	307	6	6	6	79	0	35,475	8.99
2020	333	7	6	7	82	0	35,805	7.59
2006	633	34	31	21	98	62	33,703	5.09
2020-2021, Change (%)	**-8%**	**-6%**	**-6%**	**-5%**	**-3%**	**-1%**	**-1%**	**18%**
2006-2021, Change (%)	**-52%**	**-82%**	**-81%**	**-70%**	**-19%**	**-99%**	**5%**	**76%**

5.3 CMV Emission Calculation Methodology

This section discusses the information sources used to develop physical and operational profiles of marine vessel activity, and the methods used to estimate emissions. The emission estimates are based on locally specific data for vessel movements to and from the Authority marine terminals based on AIS information provided by the U.S. Coast Guard. Information from IHS Markit (commonly known as "Lloyd's data" due to previous company ownership) has been used to develop profiles of the physical and operational parameters of OGVs along with the information from Starcrest's Vessel Boarding Program (VBP) data system.

5.3.1 Data Sources
Data sources are the sources of information used in developing the emission estimates for commercial marine vessels associated with the Authority marine terminals. The vessel categories of OGVs, assist tugs, and towboats are discussed in turn in 5.3.1.1, 5.3.1.2 and 5.3.1.3.

5.3.1.1 Ocean-Going Vessels
The AIS data for vessels that called the Authority marine terminals forms the basis of the emission estimates presented in this report. Some of the terminals provided the number of calls for their terminals, which were used to verify the AIS activity data results, when available. The AIS vessel data for the Authority marine terminals was used in conjunction with other data sources, such as IHS Markit and VBP data, to develop vessel type characteristic averages to be used for vessels that did not have specific data, and to determine speeds, routes, and dwelling times.

OGV emissions are estimated for the two general modes of ship operations: transit and dwelling. Transit refers to the activity that occurs between the study area over the water boundary and the terminal berth, including the area where vessels are maneuvering at a reduced speed within the harbor. Dwelling (also known as hoteling) refers to the vessel's operation while at berth or at anchorage. Activity levels have been evaluated based on the number of calls the vessels made to Authority marine terminals, duration of dwelling, distance traveled, and speed profiles within the channel that are all based on information developed from the AIS data using geographical information system (GIS) data analysis. The vessel specific data was used in conjunction with IHS Markit and VBP data to profile each vessel type's characteristics such as engine type, propulsion engine rating, onboard auxiliary load, IMO tier level of the vessel, and nation of registry.

The emission estimates developed for this report are based exclusively on the OGV calls to Authority-owned marine terminals, a subset of all NYNJHS calls. The number of calls of each vessel type to Authority-owned marine terminals, based on Starcrest's analysis of the AIS data, are listed in Table 5.10. Larger container vessels with a carrying capacity above 10,000 TEUs were 21% of total containership movements. Compared to 2020, there was a 13% increase in the arrivals of container vessels with a carrying capacity above 10,000 TEUs. 2021 was the first year a 16,000 TEU-sized containership called the Port.

Table 5.10: Vessel Movements for the Authority Marine Terminals

Vessel Type	Arrivals	Departures	Shifts	Total
Auto Carrier	357	356	58	771
Bulk Carrier	96	97	19	210
Container - 1000	197	196	2	395
Container - 2000	159	158	2	319
Container - 3000	50	50	2	102
Container - 4000	256	256	2	514
Container - 5000	78	78	7	163
Container - 6000	320	321	13	654
Container - 7000	22	22	1	45
Container - 8000	397	397	42	836
Container - 9000	130	128	16	274
Container - 10000	34	34	4	72
Container - 11000	101	100	0	201
Container - 12000	27	27	0	54
Container - 13000	183	185	0	368
Container - 14000	68	66	0	134
Container - 15000	15	15	0	30
Container - 16000	4	3	0	7
Cruise Ship	17	17	1	35
General Cargo	44	44	5	93
RoRo	89	89	44	222
Tanker	73	74	19	166
Total	**2,717**	**2,713**	**237**	**5,667**

Operating hours (activity) are based on the AIS distance/speed over ground calculation for periods that the vessels are in motion. Dwell times are calculated for each vessel call to a terminal or anchorage area from AIS data where the speed indicates the vessel was not in motion. Table 5.11 lists the minimum, maximum, and average dwell times at berth (hours) for the different vessel types and sizes that called at Authority terminals. In general, the average dwell time is higher as the containership capacity increased. The average dwell time is slightly higher in 2021 than in 2020 for most vessel types, except auto carrier and bulk carrier.

Table 5.11: Average Dwell Times at Berth, hours

Vessel Type	Min	Max	Average
Auto Carrier	1	275	20
Bulk Carrier	12	314	112
Container - 1000	0	210	23
Container - 2000	5	67	24
Container - 3000	8	56	23
Container - 4000	4	117	26
Container - 5000	10	50	28
Container - 6000	4	83	31
Container - 7000	14	92	40
Container - 8000	5	178	43
Container - 9000	11	108	45
Container - 10000	23	136	53
Container - 11000	13	65	39
Container - 12000	34	66	47
Container - 13000	14	184	69
Container - 14000	29	140	65
Container - 15000	36	118	69
Container - 16000	31	135	74
Cruise Ship	4	81	23
General Cargo	9	204	64
RoRo	4	80	19
Tanker	6	339	62

5.3.1.2 Assist Tugs (Harbor Craft)

Assist tug emissions have been estimated based on typical assist tug activity associated with each OGV entering or exiting from the channel (e.g., how many tugs per call, the duration of assistance). The emission factors (see section 5.3.2) were updated to reflect the Tier level of the assist tug fleet operating in the harbor in 2021. In addition, the fleet mix of assist tugs was updated to include only the latest Z-drive propulsion tugboats for assist and escort work. These newer and more powerful tugboats are used due to the larger vessels calling the Port and for greater maneuverability through restricted channels and turning basins. Table 5.12 lists the number of vessel assists for the various vessel types during the calendar year of the study.

Table 5.12: Assist Tug Operating Data and Assumptions

Vessel Type	Total Assists
Auto Carrier	1,498
Bulk Carrier	390
Containership	8,186
Cruise Ship	34
General Cargo	170
RoRo	426
Tanker	294
Total	**10,998**

5.3.1.3 Towboats (Harbor Craft)

This category of vessels is made up of the tugboats used for the barge movements associated with PANYNJ berths. The public berths at Port Newark see the majority of barge calls since these berths handle a wide range of bulk cargo such as oil, scrap metal, cement, orange juice, and salt, and these commodities are often moved by barge. There are also two container terminals with known barge calls that provide barge trips each year that are included in the barge activity for calculation of towboat emissions. The Cross-Harbor Barge service was initiated in late 2016 to reduce the number of trucks trips. In addition, there are barges that transfer sealed container city waste to rail yards, also to reduce truck trips.

A list of discrete harbor craft, including towboats, identified in the 2019 AIS data analysis was used to develop vessel characteristic assumptions. The harbor craft (i.e., vessels not included in the OGV source category) that transited through the New York/New Jersey harbor area in 2022 will be studied to see whether the engine characteristics changed in the period between 2019 and 2022 to support appropriate changes based on the latest data for future inventories.

5.3.2 Emission Estimating Methodology

Emissions are estimated for the three combustion emission source types associated with marine vessels: main (or propulsion) engines, auxiliary engines, and, for OGVs, auxiliary boilers, and for the operational modes transit (arrival/departure) and dwelling (at-berth and anchorage). Operating data and the methods of estimating emissions are discussed below. The estimates assume that all OGVs calling the port terminals used marine diesel oil (MDO) with an average sulfur content of 0.1% per IMO's requirement for the ECA. Exceptions were made for vessels that participated in the Clean Vessel Incentive program using MDO with lower sulfur content than required for the ECA during transiting and dwelling, and for other vessels with Environmental Ship Index (ESI) bunker data.

5.3.2.1 OGV Engines

Main engine emissions are only estimated for transiting mode because a vessel's main engines are turned off while the vessel is tied up at berth or at anchorage. The emissions calculation can be described using the following equation:

$$E_i \ = \ EF \ \times \ Energy_i \ \times \ FCF$$

Where:

    E_i = Emissions

    EF = emission factor, expressed in terms of g/kW-hr

    $Energy_i$ = Energy demand, calculated using the equation below as the energy output of the main engine(s) or auxiliary engines or auxiliary boiler(s) over the period of time, kW-hr

    FCF = fuel correction factor, dimensionless (discussed below in subsection **5.3.2.4**)

Energy is calculated using the following equation:

$$Energy_i \ = \ Load \ \times \ Act$$

Where:

    $Energy_i$ = Energy demand, kW-hr

    Load = maximum continuous rated (MCR) times load factor (LF) for propulsion engine power (kW); reported operational load of the auxiliary engine(s), (kW); or operational load of the auxiliary boiler (kW)

    Act = activity, hours

The propulsion engine load factor is estimated using the Propeller Law, which states that propulsion engine load varies with the cube of the ratio of actual speed to the ship's maximum rated speed, as illustrated by the following equation.

$$LF \ = \ (Speed_{Actual} \ / \ Speed_{Maximum})^3$$

Where:

    LF = load factor, dimensionless

    SpeedActual = actual speed, knots

    SpeedMaximum = maximum speed, knots

5.3.2.2 OGV Emission Factors

The ECA requirements were in effect in 2021 with the 0.1% fuel oil sulfur content limit for OGVs operating in the study area. For this report, it was assumed that all vessels that called the Authority complied with the ECA fuel requirement, and all of the engines and auxiliary boiler burned fuel with a sulfur content of 0.1% sulfur or less. In addition, several vessels under the CVI program used cleaner fuel with lower sulfur content than what is required under the ECA. Emission factors for all engine types used in this study were obtained from equations or values included in EPA's document entitled "Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emissions," dated September 2020 (EPA's EI Guidance Document)[24]. The PM_{10} and DPM emission factors are based on the following equation:

$$\textbf{PM or DPM EF} = \textbf{PM}_{\textbf{base}} \textbf{ or DPM}_{\textbf{base}} + (\textbf{S}_{\textbf{act}} \times \textbf{BSFC} \times \textbf{0.02247} \times \textbf{7})$$

Where:

    PM or DPM EF = PM_{10} or DPM emission factors adjusted for the fuel type and S content of the fuel (g/kW-hr)

    PM_{base} or DPM_{base} = Base emission factor assuming zero fuel sulfur (g/kWhr)

      = 0.1545 g/kW-hr for distillate fuel (MGO and MDO)

      = 0.5761 g/kW-hr for residual fuel (HFO)

    S_{act} = actual fuel sulfur level (weight ratio)

    BSFC = brake specific fuel consumption in g/kW-hr

    0.02247 is fraction of sulfur in fuel that is converted to direct sulfate

    7 is molecular weight ratio of sulfate PM to sulfur = 224/32 = 7

The $PM_{2.5}$ emission factor is based on the following equation:

$$\textbf{PM}_{\textbf{2.5}} \textbf{ EF} = \textbf{PM EF} \times \textbf{Fraction}$$

Where:

    PM EF = PM_{10} emission factor in g/kW-hr

    Fraction = $PM_{2.5}$ to PM_{10} ratio dependent on fuel type

      = 0.8 for HFO

      = 0.92 for MGO and MDO

The SO_x emission factor is based on the following equation:

$$\textbf{SO}_{\textbf{2}} \textbf{ EF} = \textbf{S}_{\textbf{act}} \times \textbf{BSFC} \times \textbf{2} \times \textbf{0.97753}$$

Where:

    SO_2 EF = SO_x emission factor (g/kW-hr)

    S_{act} = actual fuel sulfur level (weight ratio)

    BSFC = brake specific fuel consumption in g/kW-hr

    0.97753 is the fraction of fuel sulfur converted to SO_2 and

    2 is the ratio of molecular weights of SO_2 and S.=64/32 = 2

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[24] *https//www.epa.gov/state-and-local-transportation/port-emissions-inventory-guidance*

The CO_x emission factor is based on the following equation:

$$CO_2\ EF\ =\ BSFC\ \times\ CCF$$

Where:
    CO_2 EF = CO_x emission factor (g/kW-hr)
    BSFC = brake specific fuel consumption in g/kW-hr
    CCF= carbon content factor as a function of fuel type (CO_2/g fuel)
       = 3.206 for MGO/MDO
       = 3.114 for HFO

Table 5.13 shows BSFC by engine type used in equations for PM, SO_x and CO_2 emission factors.

Table 5.13: BSFC by Engine Type and Fuel Type for Ocean Going Vessels, g/kW-hr

Engine Category	IMO Tier	Model Year Range	BSFC
Using HFO Fuel			
Slow speed propulsion	All	All	195
Medium speed propulsion	All	All	215
Medium speed auxiliary	All	All	227
High speed auxiliary	All	All	227
Steam propulsion engine and boiler	All	All	305
Gas Turbile	All	All	305
Using MGO Fuel			
Slow speed propulsion	All	All	185
Medium speed propulsion	All	All	205
Medium speed auxiliary	All	All	217
High speed auxiliary	All	All	217
Steam propulsion engine and boiler	All	All	300
Gas Turbile	All	All	300

Tables 5.14 and 5.15 list the emission factors for propulsion and auxiliary engines using 0.1% sulfur which is the fuel that is used to be compliant with the IMO North American ECA requirement.

Table 5.14: OGV Emission Factors for Diesel Propulsion, Steam (Boiler) Propulsion and Gas Turbine Engines, g/kW-hr

Engine Category	Tier	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	HC	CO	SO_x	CO_2	N_2O	CH_4
Slow Speed Main	0	1999 and older	17.0	0.18	0.17	0.60	1.40	0.36	593	0.029	0.012
Slow Speed Main	I	2000 to 2010	16.0	0.18	0.17	0.60	1.40	0.36	593	0.029	0.012
Slow Speed Main	II	2011 to 2015	14.4	0.18	0.17	0.60	1.40	0.36	593	0.029	0.012
Slow Speed Main	III	2016 and newer	3.4	0.18	0.17	0.60	1.40	0.36	593	0.029	0.012
Medium Speed Main	0	1999 and older	13.2	0.19	0.17	0.50	1.10	0.40	657	0.029	0.012
Medium Speed Main	I	2000 to 2010	12.2	0.19	0.17	0.50	1.10	0.40	657	0.029	0.012
Medium Speed Main	II	2011 to 2015	10.5	0.19	0.17	0.50	1.10	0.40	657	0.029	0.012
Medium Speed Main	III	2016 and newer	2.6	0.19	0.17	0.50	1.10	0.40	657	0.029	0.012
Gas Turbine		All	5.7	0.01	0.01	0.10	0.20	0.59	962	0.075	0.002
Steamship Main		All	2.0	0.20	0.19	0.10	0.20	0.59	962	0.075	0.002

Table 5.15: OGV Emission Factors for Auxiliary Engines using 0.1% S, g/kW-hr

Engine Category	Tier	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	HC	CO	SO_x	CO_2	N_2O	CH_4
Medium Auxiliary	0	1999 and older	13.8	0.19	0.17	0.40	1.10	0.42	696	0.029	0.008
Medium Auxiliary	I	2000 to 2010	12.2	0.19	0.17	0.40	1.10	0.42	696	0.029	0.008
Medium Auxiliary	II	2011 to 2015	10.5	0.19	0.17	0.40	1.10	0.42	696	0.029	0.008
Medium Auxiliary	III	2016 and newer	2.6	0.19	0.17	0.40	1.10	0.42	696	0.029	0.008
High Auxiliary	0	1999 and older	10.9	0.19	0.17	0.40	0.90	0.42	696	0.029	0.008
High Auxiliary	I	2000 to 2010	9.8	0.19	0.17	0.40	0.90	0.42	696	0.029	0.008
High Auxiliary	II	2011 to 2015	7.7	0.19	0.17	0.40	0.90	0.42	696	0.029	0.008
High Auxiliary	III	2016 and newer	2.0	0.19	0.17	0.40	0.90	0.42	696	0.029	0.008

NO_x emission factors in Tables 5.14 and 5.15 are based on the IMO Tier of the vessel engines, which is based on the keel laid date provided in the IHS Markit data. When available, vessel specific NO_x emission factors from Engine International Air Pollution Prevention[25] (EIAPP) certificates are being used instead of the default values shown in Tables 5.14 and 5.15 for propulsion and auxiliary engines.

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[25] See: *https://www.navsregs.wordpress.com/2017/01/03/engine-international-air-pollution-prevention-certificate-a-handy-guide/*

Information from engine manufacturers[26] and classification societies[27] suggest that Tier III propulsion engines will not meet Tier III emission standards when operating at or below 25% load because the exhaust heat does not reach the necessary temperature for selective catalytic reduction (SCR) or exhaust gas recirculation (EGR) systems to effectively reduce emissions. As such, when Tier III main engines operated below 25% within the emissions inventory domain, the default Tier II NOx emission factor or, if available, Tier II EIAPP NO_x factors were used in emission calculations.

In addition to the auxiliary engines that are used to generate electricity for on-board uses, most OGVs have one or more boilers used for fuel heating and for producing hot water and steam. Table 5.16 shows the emission factors used for the auxiliary boilers.

Table 5.16: Emission Factors for OGV Auxiliary Boilers using 0.1% S, g/kW-hr

Engine Category	Model Year Range	NO_x	PM_{10}	$PM_{2.5}$	HC	CO	SO_x	CO_2	N_2O	CH_4
Auxiliary Boiler	All	2.0	0.20	0.19	0.10	0.20	0.59	962	0.075	0.002

5.3.2.3 OGV Low Load Adjustment
In general terms, diesel-cycle engines are not as efficient when operated at low loads compared with higher load operation. A low engine load condition may occur when a vessel is traveling at slower speeds such as maneuvering within a harbor or transiting the vessel speed reduction participation zone. During emission estimation, low load adjustment (LLA) factors are multiplied by the latest emission factors for 2-stroke (slow speed) diesel propulsion engines, adjusted for fuel differences between the actual fuel and the fuel used when the emission factors were developed. A detailed discussion and presentation of LLA used during emission estimation can be found in the latest San Pedro Bay Ports Emission Inventory Methodology Report[28].

5.3.2.4 OGV Auxiliary Engines Load Defaults
OGVs are equipped with two or more auxiliary engines that are operated to run at the most efficient level for a given load situation. For example, an OGV equipped with four auxiliary engines may run three at 75% load when power needs are high during maneuvering, to power bow thrusters as well as to meet general operating needs. While at berth, the vessel's power needs are less, so instead of running the three engines at a greatly reduced load, typically only one or two will be operated at a higher load. This saves wear and tear on the other auxiliary engines and allows the operating engine(s) to run at optimal (higher) operating levels.

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[26] See: MAN Diesel & Turbo, "Tier III Two-Stroke Technology"
[27] DNV-GL, "NOx Tier III Update: Choices and challenges for on-time compliance," November 2017.
[28] Starcrest Consulting Group, LLC, 2021, San Pedro Bay Ports Emissions Inventory Methodology Report (Version 2, pp 15-25)

In practice, vessel specific auxiliary engine and auxiliary boiler loads are not readily available for specific vessels. The information used for these estimates has been collected by Starcrest, as part of the VBP. Through the VBP, auxiliary engine and boiler data is collected from ship engineers at various ports to determine actual engine load information for the various operational modes.

Starcrest has developed a hierarchy for establishing auxiliary engine and boiler load assumptions that uses VBP data as a starting point, since that data is the most ship specific.

➢ If a vessel that calls has corresponding data in the VBP dataset, that data is used for the vessel's characteristics.
➢ If the vessel has no directly applicable data in the VBP dataset, a default is used that is based on a call-weighted average by vessel type and size range. The average is made up of vessels within the vessel type and size range that called the Authority in previous years.
➢ If the vessel has no directly applicable data in the VBP dataset and is in a vessel type and size range that has not called previously, a default is used that is the average of recently published defaults used for other port EIs.[29]

Table 5.17 lists the OGV auxiliary engine load assumptions by vessel type and mode that are used in this inventory. Transit refers to the mode of operation when a vessel is traveling within the study area but outside of the harbor, while maneuvering refers to when a vessel is operating at slower speeds within the harbor.

Table 5.17: OGV Auxiliary Engine Load by Mode, kW

Vessel Type	Transit (kW)	Manuevering (kW)	Berth Dwelling (kW)	Anchorage Dwelling (kW)
Auto Carrier	661	1,268	1,143	606
Bulk	255	283	523	261
Container - 1000	1,317	1,314	767	1,000
Container - 2000	1,461	1,962	679	770
Container - 3000	1,474	1,608	1,026	636
Container - 4000	1,335	2,508	944	880
Container - 5000	1,404	2,317	998	941
Container - 6000	1,497	2,346	980	1,312
Container - 7000	1,581	2,826	844	1,010
Container - 8000	1,648	2,596	1,221	1,128
Container - 9000	1,527	2,541	1,037	1,026
Container - 10000	1,685	2,273	1,165	1,165
Container - 11000	1,724	2,491	880	970
Container - 12000	1,600	2,300	1,050	1,050
Container - 13000	1,757	2,744	976	932
Container - 14000	1,516	2,052	1,148	1,161
Container - 15000	1,850	2,200	850	1,100
General Cargo	448	1,036	715	180
RoRo	283	849	490	283
Tanker - Chemical	460	579	1302	379

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[29] **See:** Port of Los Angeles 2021 Air Emissions Inventory, 2022 and Port of Long Beach 2021 Air Emissions Inventory, 2022

House load defaults for cruise ships (diesel electric and non-diesel electric) are listed in Table 5.18. The majority of the cruise ships that called the cruise terminal were diesel electric. Cruise ships typically do not spend any time dwelling at anchorage, so auxiliary engine loads at anchorage were not utilized in the calculations and are therefore not included in the table below.

Table 5.18: Cruise Ship Auxiliary Engine Load, kW

Vessel Type	Passenger Count	Transit (kW)	Maneuvering (kW)	Berth Dwelling (kW)
Cruise	0-1,499	3,994	5,268	3,069
Cruise	1,500-1,999	7,000	9,000	5,613
Cruise	2,000-2,499	11,000	11,350	6,900
Cruise	2,500-2,999	9,781	8,309	6,089
Cruise	3,000-3,499	8,292	10,369	8,292
Cruise	3,500-3,999	9,945	11,411	10,445
Cruise	4,000-4,499	12,500	14,000	12,000
Cruise	4,500-4,999	13,000	14,500	13,000

5.3.2.5 OGV Auxiliary Boilers

The auxiliary boiler fuel consumption data collected from vessels during the VBP was converted to equivalent kilowatts using specific fuel consumption (SFC) factors found in the ENTEC 2002 study. The average SFC value for distillate fuel is 290 grams of fuel per kW-hour, and for residual fuel it is 305 grams per kW-hour. The average kW for auxiliary boilers using distillate fuel was calculated using the following equation.

$$\textit{Average kW} = ((\textit{daily fuel}/24) \times 1{,}000{,}000)/290$$

Where:

 Average kW = average energy output of boilers, kW
 daily fuel = boiler fuel consumption, tonnes per day

As with auxiliary engines, the primary source of load data for auxiliary boilers is from the VBP, and direct values for vessels boarded are used on an individual basis for vessels boarded and their sister ships. There is no load data from the IHS Markit database by mode of operation. For vessels that have not been boarded through the VBP and that do not have a sister vessel that has been boarded, average load defaults have been developed by vessel class from the most recent data that is available from the VBP.

Auxiliary boilers are not typically used when the main engine load is greater than 20% due to heat recovery systems that are used to produce heat for steam while the ship is under way. If the main engine load is less than or equal to 20%, the auxiliary boiler load defaults shown in the table are used, depending on operating mode. Table 5.19 presents auxiliary boiler energy defaults in kilowatts for each vessel type by mode.

Table 5.19: Auxiliary Boiler Load Defaults by Mode, kW

Vessel Type	Transit (kW)	Maneuvering (kW)	Berth Dwelling (kW)	Anchorage Dwelling (kW)
Auto Carrier	98	198	336	327
Bulk	58	138	170	170
Container - 1000	119	239	599	303
Container - 2000	134	251	384	311
Container - 3000	196	294	720	439
Container - 4000	171	343	474	470
Container - 5000	245	471	545	539
Container - 6000	212	385	463	462
Container - 7000	283	558	708	701
Container - 8000	230	477	628	666
Container - 9000	367	463	535	523
Container - 10000	406	339	355	355
Container - 11000	243	441	546	543
Container - 12000	350	216	172	172
Container - 13000	209	291	588	576
Container - 14000	255	484	369	512
Container - 15000	259	395	402	402
Cruise Ship	282	361	612	306
General Cargo	67	152	198	198
RoRo	67	148	259	251
Tanker - Chemical	92	136	369	232
Tanker - Diesel-Electric	0	145	220	220

Table 5.20 presents the load defaults for the auxiliary boilers for diesel electric cruise ships.

Table 5.20: Auxiliary Boiler Load Defaults by Mode for Diesel Electric Vessels, kW

Vessel Type	Passenger Count	Transit (kW)	Maneuvering (kW)	Berth Dwelling (kW)
Cruise	0-1,499	992	784	867
Cruise	1,500-1,999	1,070	1,145	1,951
Cruise	2,000-2,499	1,382	1,773	3,005
Cruise	2,500-2,999	596	602	895
Cruise	3,000-3,499	697	1,199	1,984
Cruise	3,500-3,999	401	347	989
Cruise	4,000-4,499	0	0	503
Cruise	4,500-4,999	0	0	1,414

5.3.2.6 Assist Tugs, Towboats (Harbor Craft)
The emission estimating methodology is similar for assist tugs and towboats (as a group, termed harbor craft), based on an estimate of operating time of the vessels in service related to the Authority owned marine terminals. The basic equation for estimating main and auxiliary engine emissions is illustrated below.

$$E = EF \times Power \times LF \times Act \times FCF$$

Where:

E = emission, g/year
EF = emission factor, grams of pollutant per unit of work, g/hp-hr or g/kW-hr
Power = rated power of the engine, hp or kW
LF = load factor, which is the ratio of average load used during normal operations as compared to full load at maximum rated horsepower, it is an estimate of the average percentage of an engine's rated power output that is required to perform its operating tasks, dimensionless
Act = vessel's engine(s) activity, hr/year
FCF = fuel correction factor to reflect changes in fuel properties that have occurred over time on emissions, dimensionless

Consistent with EPA's latest Port EI Guidance document,[30] the load factor used for assist tug main engines is 50% and for auxiliary engines it is 43%. The main engine load factor for towboats is 68% and for auxiliary engines it is 43%.

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[30] *https://www.epa.gov/state-and-local-transportation/port-emissions-inventory-guidance*

The estimated operating time of assist tugs has been based on the time the tug spends assisting on an OGV call, the average number of assist tugs per OGV call, and the total number of OGV calls by vessel type to the Authority owned marine terminals. The average assist and escort time of 1.25 hours per vessel is based on the time a vessel travels to or from a berth which is confirmed by AIS data and also from conversations with pilots. The number of OGV calls changes each year.

The operating time of towboats has been estimated from the 2006 towboat detailed activity data in which time was estimated by dividing trip length by speed in mode. Since 2006, detailed origination-destination data has not been available. For this inventory, the average 2006 trip time of 2.7 hours was used. The number of barge calls are updated each year for the dedicated Cross Harbor Barge service. After the partial first year of operation, 2015, the number of barge calls has remained similar each year. The barge calls at public berths at Port Newark are also reviewed each year, but the level of activity has not changed for several years. It is acknowledged that BP is no longer a tenant of Port Newark. However, due to the similar throughput of metric tons of cargo, the public berth barge trips have been kept same.

Emission factors for all pollutants were updated based on latest detailed engine information. In 2021, the fleet composite emission factors were updated based on the latest assist tug fleet mix. This update was based on specific data such as engine model year and kilowatts, published (on their websites) by the two companies that provide assist and escort tugs. First, the emission factors were determined for the individual vessel engine(s) by looking up vessel/engine specifications from various websites, then the kilowatt weighted fleet composite emission factors were calculated separately for assist tugs. Towboat emission factors are the same as determined for the previous EI report. Table 5.21 lists the assist tug emission factors and Table 5.22 lists the towboat emission factors. The latest emission factors from EPA's Port Emissions Inventory Guidance were used to calculate the composite emission factors in 2021.

Table 5.21: Assist Tug Emission Factors, g/kW-hr

Engine	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2	N_2O	CH_4
Main Engines	4.28	0.09	0.09	0.08	1.46	0.01	679.5	0.03	0.00
Auxiliary Engines	4.87	0.10	0.09	0.16	0.93	0.01	679.5	0.03	0.00

Table 5.22: Towboat Emission Factors, g/kW-hr

Engine	NO_x	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2	CO_2	N_2O	CH_4
Main Engines	8.82	0.17	0.17	0.20	1.72	0.01	679	0.03	0.00
Auxiliary Engines	8.39	0.23	0.22	0.27	1.33	0.01	679	0.03	0.01

The engine emission factors are based on marine engine standards (i.e., Tier 1, Tier 2, Tier 3, and Tier 4). For the emissions inventory, the weighted assist tug emission factors were based on current tugboat fleet data. For 2021, the assist and escort services fleet was updated to only include the twin screw Z-Drive tugboats for the two main companies that provide assist and escort services. For towboats that transited the NYNJ harbor in 2019, information on about 195 discrete towboats from 60 operators were used to update the towboat emission factors. It should be noted that not all of these towboats called on a Authority berth but the group as a whole is assumed to represent an average fleet of towboats operating in the EI domain in 2021. Table 5.23 presents the tier distribution of the harbor craft fleet in 2021.

Table 5.23: Distribution of Harbor Craft Engines by Tier

Vessel Type	Engine Type	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4
Assist Tug	Main	0%	0%	33%	33%	33%
Assist Tug	Auxiliary	0%	0%	22%	78%	0%
Towboat	Main	60%	6%	22%	7%	5%
Towboat	Auxiliary	63%	6%	19%	11%	0%

5.4 Description of Marine Vessels and Vessel Activity

The types of marine vessels evaluated in this emissions inventory include OGVs, their assist tugs, and associated towboats, such as those that provide bunkering (refueling) services or transport materials from wharf maintenance dredging activities.

5.4.1 Ocean-Going Vessels
OGVs are seafaring vessels that are primarily involved in international trade. Generally, these vessels are over 300 feet in length and can make seaward passages greater than 25 miles. The following are types of OGVs that have been evaluated in this study:

Bulk and Break Bulk (General Cargo) Carriers carry granulated products in bulk (e.g., cement, sugar, coking coal) as well as goods known as break bulk such as machinery, steel, palletized goods, and livestock. In general, bulk carriers are slower than most other types of OGVs.

Figure 5.5: Bulk Carrier

Photograph courtesy of Petter Folkedahl Knutsen, Tuvika, Norway[31]

Containerships carry standard-sized, steel-reinforced containers. Their capacity is measured in twenty-foot equivalent units. Containers are an economical mode of marine transportation for a wide variety of dry and liquid cargos. Specialized containers can be equipped for refrigeration, and many ships have a number of electrical connections to store and power refrigerated units.

Figure 5.6: Containership at Berth

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[31] *https://www.home.nktv.no/petknu/skip.htm*

Passenger Cruise Ships have high diesel-powered generation capacities from auxiliary engines that are used to provide electricity, air conditioning, hot water, refrigeration, and other power-related demands associated with the ship.

Figure 5.7: Cruise Ship

Roll-on/Roll-off (RORO) Vessels and Car Carriers carry vehicles and other wheeled equipment. Some carry heavy-duty equipment such as military tanks, excavators, bulldozers and other similar equipment. Their unique feature is a moveable ramp that allows the vessel to load and unload wheeled vehicles and equipment. *Car Carriers* are a specialized type of RORO outfitted with lower deck heights specifically for the transport of cars, trucks, and other vehicles.

Figure 5.8: Car Carrier

Tankers carry liquid bulk cargos such as crude oil, finished liquid petroleum products, and many other liquids. Parcel tankers are specialized tankers that carry several different products at the same time in separate on-board tanks. Other liquids that may be carried include sewage, water, liquefied petroleum gas (LPG) and fruit juices.
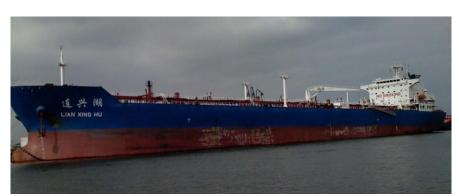
Figure 5.9: Tanker

5.4.2 Harbor Craft

Assist tugs help maneuver OGVs within the NYNJHS and during docking and departing from berths. Towboats are vessels that transport barges within the NYNJHS, moving cargo such as bunker fuel for refueling visiting OGVs. Tugboats used as assist tugs can also do duty as towboats. Pushboats are similar to towboats, except, as their name implies, they push barges rather than tow them. They can be used to move bulk liquids, scrap metal, bulk materials, rock, sand, dredged materials, and other materials.

Figure 5.10: Tugboat